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STUDIES ON THE OXIDATION-CORROSION-DEPOSITION AND THERMAL STABILITY CHARACTERISTICS OF MIL-L-7808-TYPE LUBRICANTS

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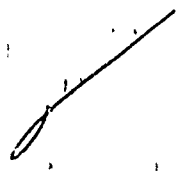

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13 ABSTRACT

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FOREWORD

This report was prepared by Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas, under Contract F33615-69-C-1295. The contract was initiated under Project No. 3048, "Fuels, Lubrication, and Hazards," Task No. 304806, "Aerospace Lubrication." The work was administered by the Lubrication Branch, Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The project engineers were Messrs. G.A. Beane, L.J. DeBrohun, and H.A. Smith (AFAPL/SFL).

This report covers one phase of work performed under the subject contract in the period of June 1, 1970 through February 1, 1972. The report was submitted by the authors in March 1972.

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Publication of this report does not constitute Air Force approval of the findings or conclusions. It is published only for the exchange and stimulation of ideas.

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ABSTRACT

This report describes test methods and procedures used in the study of the oxidation-corrosion-deposition (O-C-D) characteristics of aircraft turbine engine lubricants employing a glassware-type apparatus. Development and evaluation of a light meter device for quantitative measurement of glassware deposits are also discussed. An extensive experimental effort using eight MIL-L-7808-type lubricants is described. This study encompassed an investigation of the factors of time, temperature, moisture, and metal types in relation to lubricant breakdown in an oxidizing (air) atmosphere. A similar, less extensive program was conducted for four lubricants using an inert (nitrogen) atmosphere.

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I. INTRODUCTION

The reported program was concerned with studies of lubricant deterioration in both an oxidizing and inert atmosphere. The lubricant characteristics of oxidative or thermal breakdown, corrosion, and deposition were examined, primarily in relation to the effects produced by moisture and various metals. The effort utilized eight MIL-L-7808-type lubricants.

Two prior reports[1,2]* on related work describe some background on the evolution of equipment, procedures, and test performance criteria.

*Superscript numbers in parentheses refer to the List of References.

II. TEST APPARATUS AND PROCEDURES

A. General

The test glassware and basic procedures employed in this study are described in the test method presented in Appendix I. The method was developed under this program and prepared in the format requested by AFAPL. It is expected that the method, possibly with some revision, will utimately be included as a formalized procedure in Federal Test Method Standard No. 791B, "Lubricants, Liquid Fuels, and Related Products; Methods of Testing," Method 5307.

Subsequent paragraphs in this section will discuss any variations from, or supplementary techniques to, the basic test method.

B. Heating Units

Two thermostated oil baths[1] were used in tests with an oxidizing (air) atmosphere over a temperature range of 374° to 428°F. A thermostated aluminum block[3] was employed in all thermal stability (nitrogen atmosphere) tests at sample temperatures above 428°F. The oil bath and the aluminum block heating units both accommodate a maximum of eight sample tubes each. In both unit types, the sample tube immersion depth (into the oil or aluminum block) is 250 mm. Within the oil baths, an air space 30 mm in height separates the immersion interface and the top of the bath. The aluminum block construction employs a 100-mm thickness of insulation above the immersion interface.

C. Metal Test Specimens

The metal corrosion specimens are of the round washer-type of dimensions 3/4-in. OD and 1/4-in. ID by 0.032-in. thickness. The specific makeup of the metal specimen set was a subject of investigation, and in some series no metals were used. The composition of the various metal sets is identified in Table I by a letter code and abbreviated description. Metal set I is a seven-specimen set which is the standard group required by the method of Appendix I. The metal types are listed in Table I according to the order of stacking on the air tube, with titanium in the uppermost position. The abbreviated description refers to any variation from the standard, seven-metal set.

TABLE I. COMPOSITION OF METAL SPECIMEN SETS

Letter code	Ti	Mg	M-50 steel	Mild steel	Type 301 S.S.	Cu	CA674 bronze	AMS 4616 bronze	Ag	Al
A	None									
B	None, seven glass disks									
C	X	X		X		X			X	X
D	X	X		X			X		X	X
E	X	X		X				X	X	X
F	X	X	X	X					X	X
G	X		X	X					X	X
H	X	X		X	X				X	X
I	X	X	X	X				X	X	X
J	X		X	X				X	X	X

Abbreviated Description

A	No metals	F	No 4616
B	Glass disks	G	No Mg, no 4616
C	No M-50, with Cu, no 4616	H	No M-50, with 301 S.S., no 4616
D	No M-50, with CA674, no 4616	I	Standard metals
E	No M-50	J	No Mg

The following material specifications apply to the various metal types which were used:

Titanium	AMS 4908
Magnesium	QQ-M-44, AZ31B, condition H24
M-50 Steel	AMS 6490
Mild Steel	QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5
Type 301 S.S.	MIL-S-5059 (ASG), grade 301, half hard
Copper	QQ-C-576
Bronze	SAE-CA674
Bronze	AMS 4616
Silver	MIL-S-13282 (ord), grade A
Aluminum	QQ-A-250/4, T-3, or T-4

D. Test Procedures and Conditions

The O-C-D tests were conducted according to Procedure II (96-hr duration) of Appendix I. The only variation from the method was with respect to test duration. In many instances, the tests were terminated prior to 96 hr once it had been determined that lubricant properties exceeded performance criteria (breakpoints).

Some few O-C-D determinations were run for a period of 192 hr to increase the probability of breakpoint occurrence. In these tests, the intermediate sampling schedule was modified such that the initial sample was taken at 112 hr, and at alternating periods of 8 and 16 hr thereafter.

O-C-D test temperature was varied in increments of 9°F (5°C) from the basic temperature of 401°F (205°C), according to lubricant capability. The 401°F temperature was selected as the target value since it generally allowed for a common comparison between all lubricants. All temperatures cited herein refer to sample temperatures, not the heat medium temperature which is normally 2° to 3°F higher.

The thermal stability tests were performed with procedures identical to O-C-D testing, except for the use of nitrogen inerting gas in place of air. The inerting gas used was a high-purity, dry-grade nitrogen. Manufacturer specifications for this grade describe the gas as containing a maximum water content of 15 ppm and a typical oxygen content of 30 ppm. No attempt was made to reduce these levels further.

Prior to initiation of the thermal stability series, the air control system was repeatedly evacuated and purged with nitrogen. In addition, the assembled sample tubes, with fluid sample, were purged for 2 hr at room temperature with a nitrogen flow of 10 ℓ/hr just before test startup. Neglecting the inherent oxygen content of the nitrogen and any effect for oxygen solubility in the lubricant, it was calculated that this 2-hr purge would reduce the oxygen content within the tube to a theoretical value of 0.4 ppb by volume.

E. Deposit Rating Procedure

In previous studies[2], a detailed deposit rating procedure was formulated for numerical description of deposits occurring within the sample tubes. The procedure includes a visual rating of deposit types and area coverage to arrive at a single deposit rating value.

The visual deposit rating technique was also utilized for a portion of the present study. However, the procedure was subsequently supplanted by a rating device employing a light-absorbance principle. A schematic of the prototype light meter device is shown in Figure 1. The light chamber is a closed, fiberboard cylinder with a smooth interior surface painted flat white. Cylinder dimensions are 18-in. ID by 18-in. length. Axial alinement of the sample tube in the chamber is achieved by a pair of 2-in. rubber shaft seals (not shown in Figure 1) in tandem. One seal is mounted within the chamber cover, and the second is contained within a mounting 1 in. above the cover.

The light source is a standard F15T8/CW fluorescent lamp. The lower metal end cap of the lamp is carefully removed from the glass tube to permit greater light dispersion at the lower end. Electrical leads to the bottom of the lamp are 24-AWG bare wire fixed to the lamp sides with a clear epoxy cement. The upper section of the lamp (below

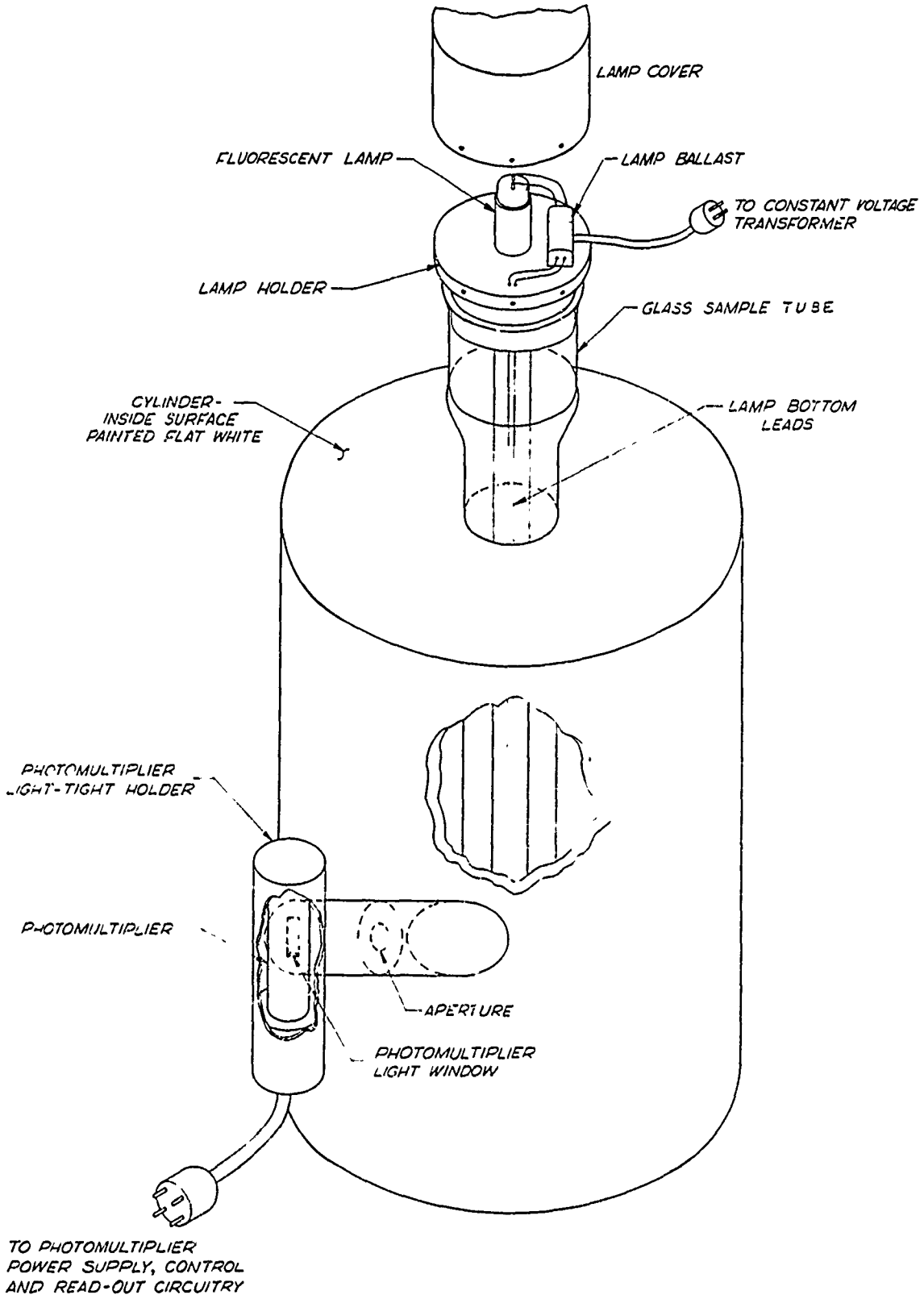

FIGURE 1. SCHEMATIC OF LIGHT METER DEVICE FOR DEPOSIT RATING

the lamp holder) is covered with a black, opaque paper for a distance such that the exposed, lower end measures 9-1/2 in. in length. Lamp power, 75 volts, is supplied by a constant voltage transformer.

The light sensor is an RCA 1P21 photomultiplier tube fitted with appropriate housing, light aperture, and polarizing filter. The filter and reduced lamp voltage are required to avoid saturation of the photo tube. This phenomenon is indicated by very slow equilibration of the tube output. Power to the photo tube is provided by a high-voltage power supply at an approximate value of 350-V dc and 0.8-milliamp current flow. Photo tube output is monitored by a precision 0 to 100 millivoltmeter. It is this output which serves as the light meter deposit rating. It is noted that the photo tube is mounted off-center of the light chamber so that the tube does not "see" any part of the glass sample tube. In this manner, a partially integrated measure of the transmitted light is obtained.

In practice, the light meter device is zeroed with a clean glass sample tube inserted in the chamber. Power to the photomultiplier is adjusted to obtain an output of 100 mV. The clean sample tube is then replaced with a post-test tube and the tube is slowly rotated, in place. The minimum millivolt reading throughout complete rotation is noted. This value is subtracted from 100; thus, increasing light meter ratings are indicative of increasing deposit severity.

As subsequently discussed, an extensive analysis was performed in examining the extent of agreement between the light meter ratings and the visual deposit ratings. It was determined that excellent correspondence of results was obtained using a slightly modified demerit scale for the visual rating procedure in the categories of very light and medium light sludge. The revised scale is shown in Table II. The only distinction between this and the original demerit scale[2] is the reduced values for very light and medium light sludge, which were formerly 3 and 4, respectively.

Using the revised visual rating, it was found that a high correlation is apparent with light meter ratings. A linear, virtually one-to-one relationship exists at least through a light meter rating of 60. Above this value, actually commencing at about 70, there is noticeable curvature in the correlation. This is due to the fact that the maximum light meter rating is 100, whereas the visual rating could exceed 1000. In addition, the light absorbance phenomenon, as such, is a logarithmic function.

TABLE II. REVISED DEMERIT SCALE FOR VISUAL DEPOSIT RATING

Deposit type	Very light	Med light	Light	Medium	Heavy
Varnish	0.5	1	2	3	5
Sludge	0.5	1	6	7	8
Granular carbon	---	---	9	10	11
Smooth carbon	---	---	12	13	14
Crinkled carbon	---	---	15	16	17
Blistered carbon	---	---	18	19	20
Flaked carbon	---	---	21	22	23

With the reliability of the light meter ratings established, the visual rating procedure was discontinued except in instances where the light meter rating was greater than 60. In this event, the revised visual rating was performed in order to determine the curvature of the relationship. Thus, in this report, no distinction is made between the two ratings at values of 60 or below. If available, the light meter rating is given. In some early tests, only the visual rating is available and these ratings were calculated according to the revised demerit scale. All deposit ratings shown above 60 refer to the revised visual rating.

F. Lubricant Performance Criteria

Lubricant studies traditionally employ the sample performance criteria of viscosity change and neutralization number as measures of oxidation stability. The work reported here also included a quantitative measure of sample deposition characteristics as evidenced by deposit ratings. In addition to these indices, oxidative and thermal stabilities were defined in terms of lubricant breakpoints as reported earlier.[1,2] The breakpoints, as applied to lubricant viscosity and neutralization number change, are expressed as the test time required to reach a specific rate of increase:

(1) Viscosity–time (hr) for the 100°F viscosity to reach a rate of increase of 1 cs/8 hr

(2) Neutralization number time (hr) for the neutralization number to reach a rate of increase of 1 mg KOH/g/8 hr.

As in earlier use of lubricant breakpoints, the present study gave primary emphasis to the neutralization number breakpoint as the major criterion of performance. However, in the later stages of the program, a decision was made to place an additional restriction on the sample neutralization number. This modification of the criterion occurred as a consequence of results obtained in several moist air O-C-D tests, particularly with specific lubricants. It was found that sample acidity increase would proceed at a rapid and constant rate, but never reach the breakpoint definition of 1 mg KOH/g/8 hr. In such cases, the sample would be assigned a breakpoint of 96+ hr, according to definition, even though the fluid had a 96-hr neutralization number of almost 10 mg KOH/g. Since values of this magnitude are clearly beyond the point of acceptable stability, it was decided to impose a maximum on the absolute value of the neutralization number. In consultation with AFAPL, a value of 4 mg KOH/g was selected as the maximum permissible neutralization number level which could be considered as within the range of lubricant acceptability.

Consequently, all data generated under this program were recalculated on the basis of a neutralization number "limit." This limit is defined as the test time (hr) to reach a neutralization number rate of increase of 1 mg KOH/g/8 hr (breakpoint), or an absolute value of 4 mg KOH/g, whichever occurs earlier.

The following summary of definitions of performance criteria is listed for reference:

Criterion	Definition
100°F Viscosity breakpoint	Time (hr) to increase of 1 cs/8 hr
Neut. no. breakpoint	Time (hr) to increase of 1 mg KOH/g/8 hr
Neut. no. limit	Earlier of times (hr) to increase of 1 mg KOH/g/8 hr or to value of 4 mg KOH/g

III. TEST LUBRICANTS

Eight test lubricants were used in the program described. All of the lubricants were originally intended for qualification under specification MIL-L-7808. Table III presents a listing of the lubricant codes and fluid property data, along with available information as to qualification status.

TABLE III. DESCRIPTION OF TEST LUBRICANTS

Lubricant code	Viscosity, cs		Neut. no., mg KOH/g	Description
	100°F	210°F		
O-66-11	16.41	4.30	0.16	MIL-L-7808 type
O-67-7	17.34	4.58	0.26	MIL-L-007808F
O-67-8	13.24	3.26	0.23	MIL-L-7808 type
O-67-9	14.87	3.69	0.04	MIL-L-7808G
O-67-20	13.48	3.25	0.21	MIL-L-7808G
O-68-7	13.69	3.38	0.08	MIL-L-7808G
O-68-17	12.96	3.45	0.25	MIL-L-7808G
O-69-2	13.53	3.25	0.04	MIL-L-7808G

IV. TEST RESULTS AND DISCUSSION

A. General

The subject program included two developmental goals. These were the final development and formal presentation of the test procedure given in Appendix I, and the construction and initial evaluation of the light meter deposit-rating device.

Experimental O-C-D test studies dealt with investigations of the effects of time, temperature, metals, and test air moisture. The influence of metal types and moisture received considerable attention. The variation of test temperature was briefly studied primarily in relation to low temperature data previously obtained. The parameter of time was utilized in several test sequences with selected lubricants and conditions to examine corrosion and deposition trends as influenced by time, up to and beyond the neutralization number limit. In these test series, the neutralization number limit was initially established in duplicate determinations at a given condition of metal set and moist or dry air. A subsequent series of runs was then performed whereby one determination was terminated at each intermediate sampling time. In this manner, lubricant deposition and metal corrosion were observed as a function of time and the state of degradation of the fluid. This concept of lubricant testing differs from the usual in that sample performance is not assessed on the basis of a fixed period of time. Rather, performance properties of interest are determined for the duration of the oxidative "life" of the lubricant, as evidenced by the neutralization number limit.

Consequently, the significance of deposit ratings was not extensively evaluated in relation to other deposition test methods, inasmuch as O-C-D test time and temperature were varied according to lubricant capability. However, all lubricants were examined in a 96-hr series at 401°F using the standard metal specimens (metal set I). These data are compared with full-scale bearing deposition test results to obtain some indication of the validity of O-C-D test deposit ratings.

Experiments to investigate lubricant thermal stability by use of nitrogen blanketing were less extensive in scope. The study was limited to four lubricants using dry or moist gas, and metal set B (glass disks) or set I. The objective of the work was to establish the upper temperature limit of the test lubricants for each condition. While distinct performance differences were observed among the four lubricants, it was difficult to categorize the fluids according to a single criterion because of the diverse degradation modes. For example, in some instances, appreciable metal corrosion was noted although viscosity and neutralization number values showed negligible fluid deterioration. Two lubricants with metal set I exhibited violent vapor refluxing and were prematurely terminated due to the resulting drop in sample temperature on the order of 40° to 50°F. In these tests, the usual performance criteria indicated only slight sample degradation. Accordingly, thermal stability performance characteristics are necessarily stated in rather broad descriptive terms.

The total effort on O-C-D and thermal stability investigations included more than 1000 individual determinations. Consequently, it was not feasible to report all intermediate and final test data here. Data summaries for all final results and performance criteria from the O-C-D tests are given in Tables XVI through XXIII of Appendix II. Similar summaries for thermal stability are contained in Tables XXIV through XXVII of Appendix II.

B. Evaluation of Light Meter Deposit Ratings

After construction and initial checkout of the light meter rating device, a significant volume of data was accumulated in assessing light meter ratings in comparison with the visual deposit ratings. It was found that excellent agreement existed between the two procedures in instances wherein the deposit types were predominantly varnish or hard carbon. In cases wherein the principal deposit type was of the very light or medium light sludge variety, it was noted that the light meter rating was consistently lower. Although the latter constituted only a small percentage of tests, the demerit rating factors for both sludge categories were originally assigned somewhat arbitrarily and it was decided to formulate revised factors to obtain a "best fit" agreement between the two procedures for this deposit type. On the basis of results for some 100 determinations, the original factors of 3 and 4 were reduced to 0.5 and 1 for very light and medium light sludge, respectively.

Using these revised demerit factors, all visual deposit ratings were recalculated. Data for 560 determinations (N) were used in obtaining the correlation regression line shown in Figure 2. Since the visual rating

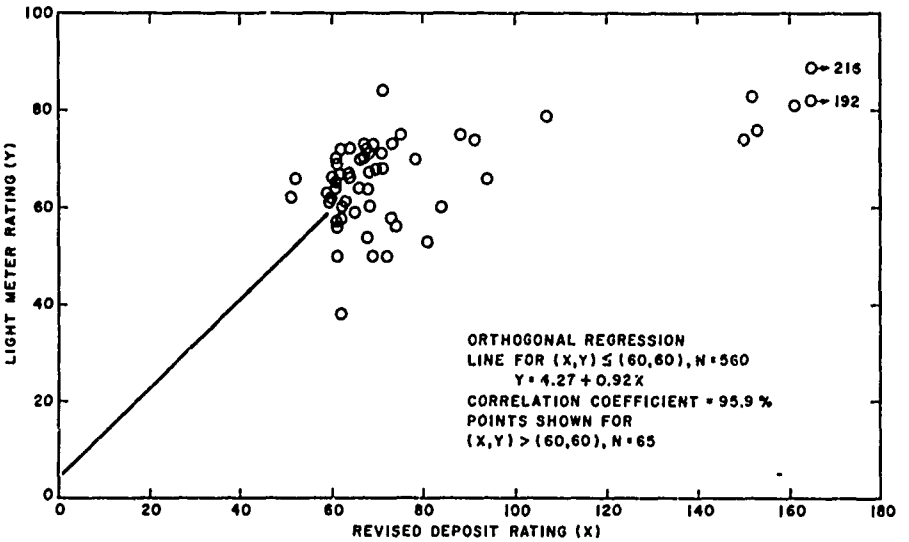

FIGURE 2. CORRELATION OF REVISED DEPOSIT RATING AND LIGHT METER RATING

must approach the maximum light meter rating of 100 exponentially, the regression line was restricted to the range of values indicating close linearity, i.e., those tests which gave a rating of 60 or less by both rating procedures. Data points beyond the 60 limit are shown in Figure 2 to demonstrate the curvature of the relationship at very high ratings.

As an indication of correlation, the correlation coefficient[4] expressed as a percentage was calculated. This statistic is a measure of the variation of results from a constant ratio, and varies from 0 (no correlation) to 100 percent (exact correlation). It should be observed that the coefficient is unaffected by the value of the ratio, i.e., if all points fall on a straight line, the correlation coefficient would be 100 percent whether the slope of the line was one or one-half.

Using all rating data of 60 or less and the revised demerit factors, a 95.9 percent correlation with the light meter was obtained. This statistic, based on 560 determinations, represents a very high degree of correspondence between the two rating procedures. In addition, as evidenced by the slope and intercept of the regression line, the correlation is virtually on a one-to-one ratio.

Figure 3 is presented to illustrate the visual severity of typical sample tube deposits in relation to the light meter deposit rating.

FIGURE 3. TYPICAL SAMPLE TUBE DEPOSITS WITH LIGHT METER RATINGS OF 4, 10, 35, AND 58 (Left to Right)

C. O-C-D Test Precision Data

Several test series were conducted to evaluate the repeatability of O-C-D test performance criteria at selected conditions. As shown in Table IV, each series included eight to ten replications. With some few exceptions, all replications were not performed during the same test period. The usual practice involved duplicate determinations initially, followed by five repeat determinations, with the eighth determination being one of the series on the effect of time.

Although both are well within the range of acceptability, data for the pooled standard deviations indicated the neutralization number limit was superior to the neutralization number breakpoint with respect to test precision. In general, both neutralization number criteria, particularly breakpoint, demonstrated a lesser precision in moist air tests in comparison with dry air tests. While there were four instances wherein the neutralization number limit standard deviation for an individual series exceeded a relatively high value of 5, there appears to be no discernible association between this occurrence and the composition of the metal set. It is probable that the four cases were simply random events in the study.

The deposition data of Table IV indicate this property could exhibit a significant variation in values. Although the pooled standard deviation of 5.3 is regarded as an acceptable overall value, several test series gave much higher precision statistics. These were generally associated with the higher rating means and, in most cases, with the use of wet air. Here again, there was no apparent relationship between metal set and deposit rating repeatability. Of the lubricant group, O-67-7 showed the poorest overall precision of ratings, but this fluid likewise produced the highest rating means at the conditions investigated.

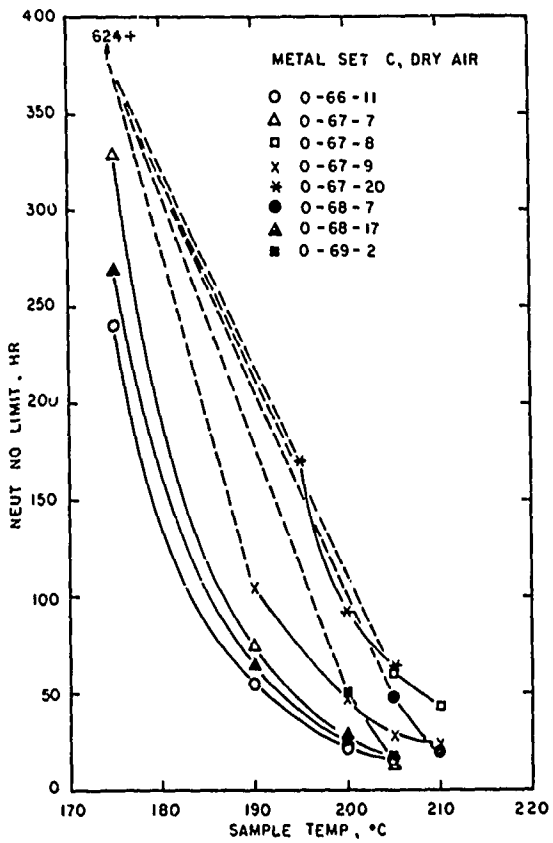

FIGURE 4 EFFECT OF TEMPERATURE ON OXIDATIVE DETERIORATION

D. Effect of O-C-D Test Temperature

As a rule, adjustment of test temperature from the primary reference of 401°F was made only to permit extrapolation of the neutralization number criteria. Thus, if no neutralization number breakpoint occurred at 401°F, sample temperature was increased in 9°F increments until, if possible, breakpoints at two temperatures were available. These data were then used to extrapolate to 401°F by means of a formula subsequently presented.

Although the major criterion of oxidative stability used herein is the neutralization number limit, it is emphasized that this concept was introduced in the later stages of the program and, thus, selection of test temperature was generally based on the breakpoint. In most dry air tests, the neutralization number breakpoint and limit were the same, i.e., acidity change reached the breakpoint rate of 1 mg KOH/g/8 hr prior to the maximum neutralization number of 4 mg KOH/g. In many wet air tests, the reverse relationship was true.

Several determinations were conducted in early work to investigate oxidative degradation over a range of test temperatures. These series, using dry air and metal set C (copper present), were for comparison with previous data[1,2], using a long duration (26 days) test procedure at the relatively low sample temperature of 347°F (175°C). Test data for neutralization number limit as a function of temperature are illustrated in Figure 4, which employs the Centigrade scale. It should be mentioned that 347°F (175°C) results for O-68-17 are those for O-67-24, a previous batch of O-68-17. In addition, the neutralization number limit with the 26-day procedure is differently defined in that the breakpoint uses a maximum rate of 1 mg KOH/g per 4 days.

TABLE IV. O-C-D TEST REPEATABILITY DATA

Lubricant code	Temp, °F	Test conditions		Termination, hr	NN Breakpoint, hr		NN Limit, hr		Light Meter	Light Rating
		Metal set	Condition of air		Mean	SD	Mean	SD	Mean	SD
O-66-11	383	F	Wet	96(9)*	19	0.5	19	0.5	4.8	1.1
O-67-7	401	A	Wet	96(8)	65	1.0	60	1.4	65†	3.7†
	401	B	Wet	96(8)	62	1.7	58	0.6	63†	3.5†
	401	B	Dry	96(8)	47	2.9	47	2.9	64†	2.5†
	401	E	Wet	72(9)	27	1.6	27	1.6	74†	18.0†
	392	F	Wet	96(9)	73	8.4	69	6.2	60†	6.0†
	392	F	Dry	72(8)	30	1.2	30	1.2	5.4†	2.5†
	392	G	Wet	96(8)	95	1.3	69	1.4	55†	4.4†
	401	I	Wet	64(8)	26	1.2	26	1.2	76†	10.1†
	401	I	Dry	48(8)	14	0.3	14	0.3	40	3.2
O-67-8	428	A	Wet	96(9)	88	3.8	35	1.2	22	2.6
	428	B	Wet	96(8)	89	0.8	34	0.5	24	3.5
	419	B	Dry	72(8)	40	2.4	40	2.4	6.5	1.4
	419	E	Wet	96(10)	42	4.6	35	2.1	33	4.3
	419	F	Wet	96(8)	83	8.7	38	1.2	1.1†	1.2†
	401	I	Wet	96(8)	93	2.3	78	1.3	12	2.8
	401	I	Dry	96(8)	77	6.1	76	5.1	5.5	0.9
O-67-9	401	E	Wet	96(10)	52	3.9	48	2.4	53†	9.0†
	401	F	Wet	96(8)	68	4.5	46	0.6	37	2.5
	401	I	Wet	96(8)	47	2.5	47	2.5	67†	6.0†
	401	I	Dry	72(8)	40	0.5	40	0.5	51	5.3
O-67-20	410	A	Wet	72(8)	43	1.9	43	1.9	9.9	2.5
	410	B	Wet	72(8)	46	2.5	46	2.5	11	2.6
	401	B	Dry	96(8)	50	1.1	50	1.1	7.5	2.6
	410	F	Wet	96(9)	50	1.3	50	1.3	9.2†	3.5†
O-68-7	401	A	Wet	96(8)	95‡	1.2‡	50	0.9	2.4	0.5
	401	E	Wet	96(8)	78	5.3	46	1.7	4.2	0.7
	410	F	Wet	96(10)	59	5.0	26	0.5	1.7†	1.5†
	401	I	Wet	96(8)	76	6.1	52	1.6	3.6	1.1
	401	I	Dry	72(8)	42	2.2	42	2.2	3.4	1.1
O-68-17	419	A	Wet	96(8)	44	2.9	26	1.6	29	5.3
	419	B	Wet	96(8)	38	8.6	26	0.7	37	10.3
	401	B	Dry	96(8)	49	3.5	49	3.5	12	12.4
	401	E	Wet	72(8)	43	3.4	38	3.7	14	9.0
	392	F	Wet	96(9)	88‡	11.9‡	42	3.1	0.1†	0.3†
	392	F	Dry	96(8)	67	3.4	67	3.4	0.0†	0.0†
	401	G	Wet	96(8)	92	1.6	32	1.2	7.6	0.9
	401	I	Wet	72(8)	49	0.7	44	1.2	10	8.5
	401	I	Dry	96(8)	49	4.0	49	4.0	5.9	1.4
O-69-2	401	A	Wet	96(8)	54	1.1	54	1.1	5.2	1.0
	401	B	Wet	96(8)	60	8.2	59	7.1	4.6	0.7
	401	B	Dry	96(8)	26	0.5	26	0.5	4.6	6.7
	401	E	Wet	96(10)	56	5.8	56	5.8	4.5	0.5
	401	F	Wet	96(8)	75	1.9	64	2.6	2.4†	1.6†
	401	I	Wet	96(8)	61	4.3	61	4.3	4.6	0.9
	401	I	Dry	72(8)	45	2.1	45	2.1	6.0	1.1
Pooled standard deviation						4.3		2.7		5.3

*Numbers in parentheses denote number of determinations comprising the means.
†Revised deposit rating.
‡A value of 96 hr was used in calculations for those determinations which showed 96+ hr.

Five of the eight lubricants shown in Figure 4 did not exhibit a neutralization number limit at 347°F within the 26-day period. However, the smoothed curves generally illustrate the very sharp response to temperature shown by lubricant deterioration. As evidenced by neutralization number limit, lubricant "life" is approximately doubled for each 10°C reduction in temperature. On the basis of these degradation curves, an equation relating temperature to the neutralization number limit and/or breakpoint was formulated for use in extrapolation outside the range of test temperature. An inverse exponential function was assumed, of the formula

$$\text{Neut. No. Limit} = C/T^n \tag{1}$$

where C is a constant and T is the Centigrade temperature. With test data at two different temperatures, the equation may be solved for the constant and the temperature exponent.

With certain conditions and lubricants which showed no neutralization number limit at 401°F, data were obtained at 410° and 419°F or 419° and 428°F and Eq. (1) was used to extrapolate to 401°F. It is believed that the extrapolation procedure gives a reasonable approximation provided the temperature range is not large. However, it is emphasized that the method yields only an approximation and extrapolation from, say. 401° to 347°F could involve appreciable error. This error may be due to the fact that the temperature exponent. n, is likewise a dependent variable of the temperature. However, it is felt more likely that the extreme sensitivity of the neutralization number limit to temperature change, which yields temperature exponents as high as 30, significantly magnifies any variation in test accuracy.

Although O-C-D test precision data indicated good overall repeatability, an example of a deviation in extrapolation accuracy may be illustrated by considering very minor variations in sample temperature. The test method of Appendix I specifies a maximum temperature variation of ±2°F. Through the use of precision calibration procedures and close monitoring of controls, the work reported here normally maintained sample temperatures within 0.5° to 1°F of the control temperature. However, even a slight deviation of this magnitude constitutes an error on the order of 10 percent when viewed in relation to data obtained at two test temperatures with only a 9°F separation. To illustrate further this effect, O-C-D results for lubricant O-67-20 using the conditions of metal set C and dry air are cited. The fluid showed corresponding neutralization number limits at 383° and 392°F of 171 and 91 hr. The limit criterion was not reached at 347°F in 26 days. Using the higher temperature data, an extrapolated neutralization number limit at 347°F of approximately 3500 hr is obtained. Applying a 10-percent error to the test data such that the error effect is additive, i.e., 100 and 154 hr rather than 91 and 171 hr, the extrapolation to 347°F gives 1280 hr. Thus, although the extreme example has been presented, it is seen that significant variation may occur in an extrapolation over a temperature range of less than 50°F.

E. Effect of Metals and Air Moisture on Lubricant Oxidation

The effects of dry and moist air and various metal specimen sets were extensively investigated in this study, and this phase of the effort constituted a major portion of the total program. Metal specimen variations were designed to examine the individual effects of copper, two bronze alloys, steels, magnesium, and the complete absence of metals. The latter condition included series with no metals or with seven glass disks of the same dimensions as the metal specimens. Use of glass disks was intended to evaluate the absence of metals while maintaining any physical effect of the specimens on dispersion of the inlet air stream.

Using the controlled temperature air moisturizer described in Appendix I, O-C-D test air moisture content was held at 10 ± 1 mg water per liter of air in runs employing moist air. The controlled temperature moisturizer was incorporated into the procedure early in the program, commencing with Test No. 506. However, prior to that test, an ambient air moisturizer had been used. This device was subject to seasonal temperature variations and, during summer months, gave moisture contents on the order of 18 to 20 mg/ℓ of air. Where comparison was possible, the moisture content reduction to 10 mg/ℓ showed no effect on lubricant performance criteria.

A comparison of the effect of metal sets and air moisture at 401°F is given in Table V for the eight test lubricants. Lubricant O-66-11 exhibited very poor oxidative stability at this temperature and at most conditions indicated a neutralization number limit of less than 8 hr. The fluid did show an unusual, beneficial effect for the presence of copper (metal set C), using both wet and dry air.

TABLE V. LUBRICANT PERFORMANCE COMPARISON AT 401°F

Metal set	Condition of air	Mean neutralization number limit at 401°F, hr							
		O-66-11	O-67-7	O-67-8	O-67-9	O-67-20	O-68-7	O-68-17	O-69-2
A (no metals)	Wet	<8	60	105*	59	77	50	46	54
B (glass disks)	Wet	<8	58	104*	59	74	47	46	59
B (glass disks)	Dry	<8	47	78	56	50	40	49	26
C (no M-50, with Cu, no 4616)	Wet	18	18	62	35	70	44	<8	50
C (no M-50, with Cu, no 4616)	Dry	16	14	60	28	66	48	<8	51
D (no M-50, with CA674, no 4616)	Wet	<8	24	79	48	96	38	35	68
E (no M-50)	Wet	<8	27	74	48	74	46	38	56
F (no 4616)	Wet	<8	26	96+	46	86	42	36	64
F (no 4616)	Dry	<8	25	70	52	50	25	46	26
G (no Mg, no 4616)	Wet	<8	51	68-96+	45	90	39	32	68
H (no M-50, with 301 S.S., no 4616)	Wet	<8	25	—	46	—	—	33	—
I (standard metals)	Wet	<8	26	78	47	74	52	44	61
I (standard metals)	Dry	<8	14	76	40	70	42	49	45
*Result is extrapolated.									

Lubricant O-67-7 displayed most of the responses normally observed in this study. No performance effect was evident for the presence of glass disks in comparison with no metals (set A). Moist air resulted in slightly improved oxidative stability using glass disks and most metal sets, although the effect was insignificant with metal sets C and F. The presence of copper caused some reduction in O-67-7 life, however, results for metal set G indicated a significant, deleterious effect for magnesium. Of the lubricant group, O-67-7 was unique with respect to its reaction to magnesium.

The most superior overall performance in O-C-D testing was shown by lubricant O-67-8. The data of Table V indicate a beneficial effect for moist air in the series with glass disks and metal set F. With copper (set C) or 4616 bronze (set I vs set F) present, the advantage of moisture was negligible. In moist air tests with no metals, it was necessary to extrapolate the neutralization number limits for O-67-8. An extrapolation was also in order for the moist air determinations using set F, but the technique was not applicable in this case. Runs with these conditions at 401°F did not reach a neutralization number limit in 96 hr with O-67-8. Experiments at higher temperatures showed a relatively small effect for temperature as listed here:

Sample Temp, °F	Neut. No. Limit, hr
401	96+
410	50
419	38
428	31

Extrapolation of the results obtained at 410°F and above yields a 401°F value of approximately 65 hr. This inconsistency is presumably related to the fluid's mode of deterioration with moisture present whereby neutralization number increases at a rapid but constant rate such that no breakpoint occurs. This phenomenon was characteristic of tests on O-67-8, O-68-7, and O-68-17, and resulted in the subsequent adoption of a neutralization number limit.

Lubricant O-67-9 exhibited the usual response to moisture and metals although the effects were slight. Copper was noticeably deleterious with this fluid but there was little distinction between the other metal sets.

Results for O-67-20 given in Table V indicate a strong beneficial effect for moisture with glass disks and metal set F. However, the effect was small with sets C and I. The use of copper with O-67-20 was not noticeably harmful, particularly when comparing the dry air copper tests with glass disks or metal set F. In general, this lubricant showed essentially no reduction in stability as a consequence of metals being present and, in fact, gave increased neutralization number limits in many instances.

Lubricant O-68-7 exhibited reactions to moisture and metals very similar to O-67-20, but at a lesser overall stability level.

The performance of O-68-17 in the O-C-D test phase was characterized by significantly accelerated degradation in the presence of copper. In addition, the results of Table V show that O-68-17 was the sole fluid which did not indicate improved stability by the use of moist air with any metal set. In fact, with metal set F, the lubricant showed the better resistance to deterioration with the dry air condition.

The final test lubricant listed in Table V, O-69-2, showed a significant moisture effect with glass disks and metal sets F and I. Data for the wet and dry air series using set C were in close agreement. O-69-2 was not adversely affected by the presence of any of the metal sets. Comparing the dry air series, it is seen that the neutralization number limit was actually lengthened in the series with sets C and I as opposed to the 26-hr value for glass disks.

In classifying performance trends and the effects produced by moisture and various metals, it is obvious that firm, general rules are not applicable. The effects were diverse, depending on the test lubricant. The effects were also interrelated in some cases. In summary, moist air normally resulted in improved oxidative stability. O-68-17 was a notable exception to this trend, and the effect was negligible for other fluids with certain metal sets, particularly set C. The effect of copper was generally detrimental except in the case of lubricant O-66-11. Lubricant O-67-7, likewise, showed a significant reduction in stability associated with the presence of magnesium. As a general observation, it is not possible to state that metals, as such, were deleterious. There were several conditions with lubricants O-67-20, O-68-7, O-68-17, and O-69-2 which indicated either no effect or a favorable influence attributable to the presence of metals.

Because of these variable effects, it is apparent that lubricant evaluation tests intended to screen fluids would be appreciably influenced by the selected conditions, even at a given test temperature. This is illustrated in Table VI which presents a relative ranking of lubricants according to neutralization number limit. Based on the average ranking, O-67-8 was clearly the most superior of the group, and O-66-11 indicated the lowest ranking. The remaining lubricants showed considerable fluctuation of ranking depending on the metal or moisture condition. The largest spread of rankings was shown by O-68-17 which varied from third in the dry air, seven metals series to eighth in the series with copper.

F. Corrosion-Deposition Results

The lubricant characteristics of corrosion and deposition were usually investigated in relation to the neutralization number limit and test time. However, 96-hr O-C-D test data at 401°F were obtained with metal set I and wet air to examine the correspondence with full-scale bearing deposition test results[5] similar to the test required in the MIL-L-7808G specification. It is noted that lubricants O-66-11, O-67-7, and O-68-17 were run far beyond their degradation capabilities in the 96-hr O-C-D test in order to obtain deposit ratings for a comparable test duration for all eight lubricants. Table VII presents these data in relation to the bearing test. A reasonably satisfactory correspondence between ratings is illustrated by the plot of these results in Figure 5. Both test procedures identified O-67-7 as least satisfactory in deposition characteristics. Some disagreement between the two tests was obtained for O-66-11. The O-C-D test deposit rating of 22 was low in relation to the bearing test rating mean of 76. However, it should be mentioned that the latter showed a large spread of ratings in four determinations, ranging from 48 to 99. The remaining six lubricants indicated only slight separation in the bearing test with mean ratings ranging from 36 to 55. The O-C-D test ratings identified lubricants O-67-9 and O-68-17 as being noticeably less satisfactory within this subgroup, particularly comparing O-67-9 versus O-67-8, and O-68-17 versus O-67-20 or O-68-7.

TABLE VI. LUBRICANT PERFORMANCE RANKING BASED ON NEUTRALIZATION NUMBER LIMIT AT 401°F

Metal set	Condition of air	Relative ranking at 401°F							
		O-66-11	O-67-7	O-67-8	O-67-9	O-67-20	O-68-7	O-68-17	O-69-2
A (no metals)	Wet	8	3	1	4	2	6	7	5
B (glass disks)	Wet	8	5	1	3.5	2	6	7	3.5
B (glass disks)	Dry	8	5	1	2	3	6	4	7
C (no M-50, with Cu, no 4616)	Dry	6.5	6.5	2	5	1	4	8	3
C (no M-50, with Cu, no 4616)	Dry	6	7	2	5	1	4	8	3
D (no M-50, with CA674, no 4616)	Wet	8	7	2	4	1	5	6	3
E (no M-50)	Wet	8	7	1.5	4	1.5	5	6	3
F (no 4616)	Wet	8	7	1	4	2	5	6	3
F (no 4616)	Dry	8	6.5	1	2	3	6.5	4	5
G (no Mg, no 4616)	Wet	8	4	2	5	1	6	7	3
I (standard metals)	Wet	8	7	1	5	2	4	6	3
I (standard metals)	Dry	8	7	1	6	2	5	3	4
Average Ranking		7.7	6.0	1.4	4.1	1.8	5.2	6.0	3.8

The normal O-C-D test procedure used in assessing lubricant corrosion and deposition involved a test series whereby one determination was terminated at each sampling period, with the total duration greater than the neutralization number limit. In this way, all performance criteria could be evaluated in relation to the stable "life" of the fluid. Test series of this type were conducted only for selected lubricants and metal sets and, of course, only if the conditions produced significant corrosion and deposits. Prior to data presentation, it is observed that all determinations are single runs. Although additional runs for a given test duration may be available for averaging, it is believed that the effect of time is more clearly seen in the sequence specifically conducted for that purpose. Thus, the test precision is artificially enhanced by considering data obtained only in the same time and test sequence.

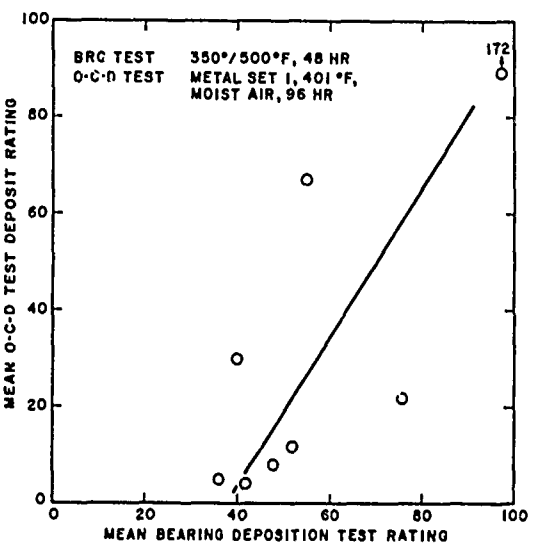

FIGURE 5. CORRELATION OF O-C-D AND BEARING TEST DEPOSIT RATINGS

Results for O-67-7 in various test series of this type are given in Table VIII. Although the summary tables of Appendix II show that a number of metal types encountered significant attack (weight change of ±0.20 mg/cm^2 or more) at various conditions, magnesium was the only metal which did so for any lubricant in the time-sequence series. The corrosion data for O-67-7 in Table VIII indicate that appreciable attack was not coincident with the neutralization number limit, but did initiate at a time near the limit. Magnesium corrosion also appeared to accelerate during the test period beyond the neutralization number limit. It is seen that very early magnesium attack occurred with metal set I and dry air, corresponding to the earlier neutralization number limit in this series compared to the moist air condition.

The deposition time trends for O-67-7 were generally consistent and showed no apparent relationship with neutralization number limit. The lubricant produced substantial deposit formations in the period of 0 to 16 hr. Thereafter, deposit ratings indicated only a slight, gradual increase with time. Little or no effect on the severity of O-67-7 deposits was attributable to metal specimen set or air moisture.

TABLE VII. CORRELATION OF O-C-D AND BEARING TEST DEPOSIT RATINGS

Lubricant code	Mean 350°/500°F Brg test rating	Mean O-C-D test deposit rating at 96 hr*
O-66-11	76(4)	22(2)
O-67-7	97(6)	172(2)
O-67-8	52(4)	12(8)
O-67-9	55(4)	67(8)
O-67-20	48(6)	8(3)
O-68-7	42(3)	4(8)
O-68-17	40(3)	30(2)
O-69-2	30(3)†	5(8)

Numbers in parentheses denote the number of determinations comprising the mean.

*Test conditions: metal set I, 401°F, moist air.
†Data for O-67-11, a different batch of O-69-2.

Table IX presents the results for O-67-8 as a function of time. Significant magnesium corrosion with this fluid occurred only at a time some 20 to 25 hr beyond the neutralization number limit. With metal sets A, B, and E, the O-67-8 series was conducted at 419° or 428°F and deposit ratings were relatively mild even at these temperatures. Examined in relation to time, these ratings were essentially constant through 72 hr. However, the 88- and 96-hr ratings in these series suggest incipient acceleration of deposits in the later stages of the tests. The sequences with metal set I indicated virtually no change in ratings throughout 96 hr, although the neutralization number limit was reached in the 72-, 88-, and 96-hr determinations with both wet and dry air.

The performance of O-67-9 in the time-sequence series is tabulated in Table X. The corrosion-deposition trends with this lubricant were similar to those of O-67-7. Significant deposits were formed in the initial 16 hr of test with only slight increases in subsequent ratings. Magnesium attack generally accelerated in the later test periods past the

TABLE VIII. CORROSION-DEPOSITION TIME TRENDS FOR O-67-7

Test Time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating
Metal set A, 401°F, moist air				Metal set B, 401°F, moist air			Metal set B, 401°F, dry air		
16	16+	None present	36	16+	None present	38	16+	None present	36
24	24+		43	24+		40	24+		35
40	40+		50	40+		48	40+		40
48	48+		51	48+		54	48+		46
64	60		54	59		54	48		52
72	60		60	58		58	51		58
88	60		61	58		61	50		65
96	60		67	58		66	44		62
Metal set E, 401°F, moist air				Metal set F, 392°F, moist air			Metal set G, 401°F, moist air		
16	16+	0.00	35	16+	-0.02	28	16+	None present	32
24	24+	-0.16	40	24+	-0.06	31	24+		38
40	28	-0.14	47	40+	-0.06	32	40+		43
48	26	-1.76	58	48+	-0.16	36	48+		43
64	29	-1.86	61	64+	-0.42	49	51		44
72	26	-5.78	60	69	-0.50	52	51		47
88				69	-0.78	57			
Metal set I, 401°F, moist air				Metal set I, 401°F, dry air					
16	16+	0.00	34	15	-0.70	30			
24	24+	-0.22	38	15	-1.58	37			
40	30	-0.28	48	15	-18.56	39			
48	26	-2.06	54	15	-33.46	45			
64	26	-25.4	50						
72									
88									
96									

neutralization number limit. The corrosion data for O-67-9 with metal set I did indicate a unique effect for air moisture. Using wet air, significant magnesium corrosion occurred in the 72-hr determination with a 48-hr neutralization number limit. The corresponding determination with dry air gave a 40-hr limit but no

TABLE IX. CORROSION-DEPOSITION TIME TRENDS FOR O-67-8

Test time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating
Metal set A, 428°F, moist air				Metal set B, 428°F, moist air			Metal set E, 419°F moist air		
16	16+	None present	5	16+	None present	5	16+	0.00	19
24	24+		6	24+		7	24+	0.00	18
40	34		8	32		5	36	−0.06	20
48	36		8	34		7	39	−0.12	15
64	37		10	34		9	38	−0.36	20
72	36		10	34		11	37	−2.10	19
88	35		16	34		18	37	−2.84	29
96	37		20	34		28	37	−4.58	36
Metal set I, 401°F, moist air				Metal set I, 401°F, dry air					
16	16+	0.00	6	16+	0.00	6			
24	24+	−0.02	8	24+	0.00	7			
40	40+	−0.02	12	40+	0.00	7			
48	48+	−0.06	10	48+	−0.02	7			
64	64+	−0.04	12	64+	0.00	7			
72	72	−0.02	12	69	−0.02	6			
88	78	−0.08	12	67	−0.04	6			
96	78	−0.18	8	76	0.00	6			

TABLE X. CORROSION-DEPOSITION TIME TRENDS FOR O-67-9

Test time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating
Metal set A, 401°F, moist air				Metal set B, 401°F, moist air			Metal set B, 401°F, dry air		
16	16+	None present	25	16+	None present	30	16+	None present	26
24	24+		33	24+		30	24+		32
40	40+		39	40+		36	40+		36
48	48+		40	48+		38	48+		41
64	57		42	59		42	54		38
72	59		44	60		42	54		40
88	58		47	60		41	53		46
96	59		47	61		45	59		46
Metal set E, 401°F, moist air				Metal set F, 392°F, moist air			Metal set G, 401°F, moist air		
16	16+	+0.02	31	16+	-0.02	21	16+	None present	26
24	24+	+0.02	34	24+	0.00	25	24+		31
40	40+	+0.04	37	40+	-0.08	25	40+		34
48	47	+0.02	42	48+	0.00	26	43		38
64	49	0.00	45	58	−0.16	27	44		40
72	49	-0.24	51	59	−0.18	27	43		40
88	49	-0.42	54	59	2.74	28	43		36
96	49	1.40	55	59	−6.58	26	44		38
Metal set I, 401°F, moist air				Metal set I, 401°F, dry air					
16	16+	-0.02	31	16+	-0.02	22			
24	24+	−0.02	33	24+	0.00	28			
40	40+	−0.04	36	40	0.00	34			
48	45	−0.08	40	40	0.00	40			
64	48	-0.06	51	40	-0.02	49			
72	48	-0.64	57	40	0.00	57			
88	48	-1.16	61						
96	48	2.08	60						

magnesium weight change. In this instance, the data imply that moisture exerts a major influence in magnesium corrosion.

The corrosion results in Table XI for O-67-20 did not exhibit a noticeable effect for moisture with metal set I. Magnesium attack occurred in the later test periods for both conditions of air moisture. Deposit ratings for all O-67-20 series were mild and indicated virtually no change with test time.

Lubricant O-68-17, as shown in Table XII, indicated significant deposit buildup in the period of 48 to 96 hr in the series at 419°F with no metals or glass disks present. However, in both series, the neutralization number limit occurred at about 25 hr, with no apparent relation to the deposition trend. Deposits in the series at 392° and 401°F were slight. Corrosion results for O-68-17 showed significant weight losses for magnesium at some 20 to 30 hr following the neutralization number limit. In each series containing magnesium, the penultimate determination

TABLE XI. CORROSION-DEPOSITION TIME TRENDS FOR O-67-20

Test time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit hr	Mg weight change mg/cm²	Deposit rating
Metal set A, 410°F, moist air				Metal set B, 410°F, moist air			Metal set I, 401°F, moist air		
16	16+	None	5	16+	None	6	16+	+0.02	9
24	24+	present	9	24+	present	8	24+	−0.02	9
40	40+		9	39		15	40+	0.00	14
48	42		10	41		12	48+	0.00	15
64	42		8	45		12	64+	0.00	12
72	41		7	49		14	72	−0.06	17
88							73	−0.14	8
96							73	−0.50	8
Metal set I, 401°F, dry air									
16	16+	0.00	6						
24	24+	0.00	8						
40	40+	0.00	12						
48	48+	0.00	15						
64	64+	0.00	8						
72	67	0.00	10						
88	65	−0.72	12						
96	69	−0.52	12						

TABLE XII. CORROSION-DEPOSITION TIME TRENDS FOR O-68-17

Test time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating
Metal set A, 419°F, moist air				Metal set B, 419°F, moist air			Metal set F, 392°F, moist air		
16	16+	None	3	16+	None	5	16+	0.00	0
24	24+	present	3	23	present	5	24+	+0.02	0
40	25		4	25		6	40+	−0.04	0
48	16		5	24		9	40	+0.02	0
64	24		13	25		12	40	−0.02	0
72	24		18	25		19	40	−5.06	0
88	26		28	24		34	40	−0.48	0
96	25		40	24		46			
Metal set I, 401°F, moist air				Metal set I, 401°F, dry air					
16	16+	+0.02	2	16+	0.00	4			
24	24+	+0.04	4	24+	0.00	4			
40	40+	+0.04	5	40+	+0.02	5			
48	45	+0.04	5	48+	0.00	5			
64	44	−4.68	7	51	−0.02	6			
72	45	−3.70	9	51	−0.32	7			
88				50	−3.74	6			
96				52	1.54	7			

showed a high metal weight loss, whereas the final run gave a somewhat lower loss. No explanation can be offered for this phenomenon. It is conceivable that the effect is simply due to the repeatability of the corrosion data; however, the consistency of the phenomenon tends to contradict that interpretation.

Lubricant O-69-2 was investigated only with metal set I in this phase of the study. As seen in Table XIII, lubricant deposits in both the wet and dry air series were insignificant. Magnesium corrosion with wet air was

TABLE XIII. CORROSION-DEPOSITION TIME TRENDS FOR O-69-2

Test time, hr	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating	Neut. no. limit, hr	Mg weight change, mg/cm²	Deposit rating
	Metal set I, 401°F, moist air			Metal set I, 401°F, dry air		
16	16+	−0.02	4	16+	−0.02	3
24	24+	0.00	4	24+	0.00	4
40	40+	+0.02	5	40+	0.00	4
48	48+	0.00	4	42	0.00	4
64	64	−0.02	6	42	−0.06	4
72	64	+0.02	6	42	−0.12	5
88	64	−6.40	5			
96	64	−4.10	6			

obtained at approximately 25 hr past the neutralization number limit and, once again, the maximum weight loss was not for the maximum test duration.

G. Thermal Stability Test Results

This phase of the program was confined to four lubricants using a moist or dry gas (nitrogen) environment and glass disks (set B) or seven metals (set I). The original objective of the test schedule was to adjust the sample temperature in 9°F increments until a neutralization number limit was obtained for a given test condition and lubricant; however, for various reasons to be discussed, this was not accomplished in every case. A summary of all thermal stability test results is given in Tables XXIV to XXVII of Appendix II.

Thermal stability test performance criteria for all runs with dry nitrogen are shown in Table XIV. Lubricant O-67-7 indicated a 42-hr neutralization number limit at 482°F with glass disks. The test temperature was raised to 491°F and then 518°F in an unsuccessful attempt to reach a viscosity breakpoint. At the highest temperature, the lubricant did yield significant deposits as evidenced by the deposit rating of 70. With the seven-metal specimen set present, O-67-7 gave the reverse relationship for acidity and viscosity, i.e., a viscosity breakpoint occurred rather early in the test but no neutralization number limit was reached. However, it is noted that all such tests were terminated prior to 96 hr as a consequence of severe and violent condensate refluxing which ultimately caused a sample temperature drop on the order of 40 to 50 degrees F.

Although O-68-17 exhibited a slightly higher temperature tolerance, the fluid's performance was in all other respects similar to O-67-7 in the dry nitrogen series. With both lubricants, all determinations with metals showed severe magnesium attack, and the specimen was essentially destroyed. However, in every such test, the sample neutralization number was less than 1 mg KOH/g at the end of test. It is theorized that these data reflect a continuous process of acid consumption in the reaction with magnesium. The products of the process could also be responsible for the occurrence of viscosity breakpoints in metal tests for these two lubricants.

As seen in Table XIV, O-67-9 gave a 38-hr neutralization number limit at 527°F with no metals. With metal set I, lubricant performance was seemingly improved with respect to sample acidity, but severe corrosion was encountered as well as significant viscosity increases. Here again, it is suspected that corrosion and reduced neutralization number levels are interrelated.

The performance of lubricant O-67-20 in the thermal stability series was similar to O-67-9, except that the former demonstrated a very high temperature capability. Testing with no metals and O-67-20 was suspended after

TABLE XIV. THERMAL STABILITY TEST RESULTS–DRY NITROGEN

Lubricant Code	Test Conditions			Breakpoint, hr		Neut. no. limit, hr	Significant corrosion	Deposit rating
	Temp, °F	Metal set	Termination, hr	Neut. no.	100°F vis			
O-67-7	482(2)	B	96	96+	96+	42	—	4
	491(2)	B	96	<16	96+	<16	—	7
	518(1)	B	96	<8	96+	<8	—	70
	473(2)	I	64*	64+	54	64+	Mg	4
	482(2)	I	48*	48+	27	48+	Mg	6
	491(2)	I	48*	48+	20	48+	Mg	8
O-67-9	527(2)	B	96	96+	96+	38	—	5
	536(2)	B	96	<16	96+	<16	—	12
	554(2)	B	96	<8	96+	<8	—	16
	509(2)	I	96	96+	93	96+	Mg, M-50, Fe	7
	527(2)	I	96	96+	57	62	Mg, M-50, Fe	20
	536(2)	I	96	96+	44	62	Mg, M-50, Fe	20
	545(2)	I	96	60	36	44	Mg, M-50, Fe	19
O-67-20	518(1)	B	96	96+	96+	96+	—	14
	536(2)	B	96	96+	96+	96+	—	28
	554(1)	B	96	96+	96+	96+	—	25
	572(2)	B	96	96+	96+	96+	—	26
	590(2)	B	96	96+	96+	96+	—	12
	608(2)	B	96	96+	96+	96+	—	17
	644(2)	B	96	96+	96+	96+	—	47
	581(2)	I	96	96+	96+	96+	Mg, M-50, Fe	13
	590(2)	I	96	64	96+	64	Mg M-50, Fe	27
	608(2)	I	96	31	96+	31	Mg M-50, Fe	32
O-68-17	491(2)	B	96	96+	96+	51	—	10
	509(2)	B	96	<16	96+	<16	—	7
	518(1)	B	96	<8	96+	<8	—	11
	473(2)	I	72*	72+	66-72+	66-72+	Mg	4
	491(2)	I	48*	48+	30	48+	Mg	4
	509(2)	I	16*	16+	16+	16+	Mg	4

Results are mean values based on the number of determinations shown in parenthesis.

*Tests terminated prematurely due to violent refluxing and associated sample temperature drop.

runs at 644°F, at which point there was little change in sample neutralization number or viscosity, although significant deposit ratings were obtained. The fluid exhibited a much lower temperature tolerance with metals present with significant metal corrosion occurring at 581°F and an initial neutralization number limit occurring at 590°F.

In several thermal stability tests with or without metals, dry or wet nitrogen, a cyclical tendency was observed for sample neutralization number particularly with O-67-9 and O-67-20. The phenomenon is illustrated by data for O-67-20 shown in Figure 6. Intermediate sample results show that sample acidity passed through a maximum for both conditions. Thus, in the seven-metals tests, the data summary of Table XXVI lists a test time of approximately 40 hr to reach a neutralization number of 4 mg KOH/g, while the end of test neutralization number was in fact less than 4 mg KOH/g. It is conjectured that this cycling of values may be related to acid losses through volatilization and, with metals present, losses via acid-metal reactions to form insoluble salts. It is noted, for example, that instances of significant metal corrosion with O-67-20 (Table XXVI) were also frequently associated with high sludge percentages. If it is assumed that magnesium is the principal metal reactant involved, the neutralization number upturn in the later hours of the test, as shown in Figure 6, may simply be due to the metal's depletion.

The results of the moist nitrogen series are given in Table XV. There was no significant performance distinction attributable to moisture in comparison to dry [illegible] for any of the lubricants investigated. There was a slight

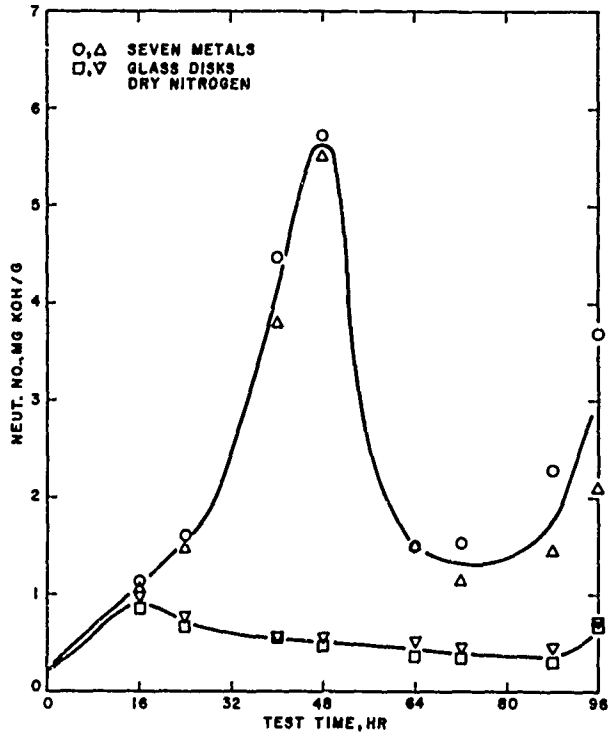

FIGURE 6. NEUTRALIZATION NUMBER CHANGE IN 608°F THERMAL STABILITY TESTS ON O-67-20

deleterious effect for moisture when comparing neutralization number limits and viscosity breakpoints between Tables XIV and XV at a given temperature, but the effect was small.

Lubricants O-67-7 and O-68-17 also exhibited excessive refluxing with metals in the moist gas series (Table XV), and further examination of the effect was conducted in this instance. Both fluids were tested using metal set J, which is the same as set I but without magnesium. Removal of magnesium resulted in a pronounced effect on lubricant thermal stability. The absence of the metal eliminated the severe refluxing phenomenon and the viscosity breakpoints which were observed in metal set I runs. In addition, appreciable sample neutralization numbers were obtained with relatively early neutralization number limits. Lubricant O-67-7 evidenced significant corrosion of the steel and bronze specimens, while O-68-17 showed mild steel (Fe) attack with metal set J.

TABLE XV. THERMAL STABILITY TEST RESULTS–MOIST NITROGEN

Lubricant code	Test conditions			Breakpoint, hr		Neut. no. limit, hr	Significant corrosion	Deposit rating
	Temp, °F	Metal set	Termination, hr	Neut. no.	100°F vis			
O-67-7	482	B	96	96+	96+	38	—	4
	491	B	96	<16	96+	<16	—	4
	473	I	48*	48+	42	48+	Mg	4
	482	I	40*	40+	33	40+	Mg	7
	491	I	24*	24+	19	24+	Mg	4
	491	J	96	96+	96+	31	M-50, Fe bronze	14
O-67-9	509	B	96	96+	96+	51	—	5
	527	B	96	70	96+	21	—	8
	491	I	96	96+	96+	96+	Mg, Fe	4
	509	I	96	96+	92	85	Mg M-50, Fe	5
	527	I	96	70	52	47	Mg, M-50, Fe	10
O-67-20	590	B	96	96+	96+	96+	—	20
	608	B	96	96+	96+	96+	—	35
	644	B	96	96+	96+	96+	—	54
	491	I	96	96+	96+	96+	Mg	5
	590	I	96	96+	96+	71-96+	Mg, M-50, Fe	30
	608	I	96	<16	96+	<16	Mg, M-50, Fe bronze	19
O-68-17	491	B	96	64	96+	24	—	4
	509	B	96	<16	96+	<16	—	6
	518	B	96	<16	96+	<16	—	8
	473	I	48*	48+	48+	48+	Mg	4
	482	I	40*	40+	40+	40+	Mg	4
	491	I	24*	24+	24+	24+	Mg	6
	509	I	20*	20+	<16	20+	Mg	5
	509	J	96	<16	96+	<16	Fe	6

Results are mean values for duplicate determinations.

*Tests terminated prematurely due to violent refluxing and associated sample temperature drop.

V. CONCLUSIONS

Development and preliminary evaluation of a light meter device to rate glassware deposits were achieved. Light meter ratings indicate good precision of values and excellent correspondence with visual deposit ratings. The significance of O-C-D test deposit ratings in relation to other lubricant deposition tests was not extensively explored. However, one 96-hr O-C-D test series with a seven-metal specimen set showed reasonable agreement with full-scale bearing test data. It is concluded that additional study of this aspect of the O-C-D test, specifically directed toward investigation of deposit rating capability, is warranted.

On the basis of 392 individual determinations, the repeatability of major O-C-D test performance criteria was very satisfactory as evidenced by pooled standard deviations of 2.7 for the neutralization number limit and 5.3 for deposit rating. It is believed that the test method described in Appendix I provides a meaningful tool for the evaluation of lubricant stability in the presence of metals.

Conclusions with regard to the effects of metals and air moisture in the O-C-D test are dependent upon the test lubricant. In general, moist air usually enhanced oxidative stability; however, the effect was negated for some lubricants with metals present, particularly the metal set containing copper. As such, copper normally exhibited a detrimental effect. One lubricant, O-67-7, indicated a significant deleterious effect for the presence of magnesium in the O-C-D series. It is concluded that metals, as a class, do not necessarily promote lubricant degradation in an oxidizing environment. Four of the eight lubricants examined in this study showed either no change or improved oxidative resistance due to the presence of metals in particular test series.

As a consequence of the diverse responses to metals and moisture, it is evident that the relative ranking of lubricants in the O-C-D test is significantly influenced by these conditions. In a relative comparison of the eight test lubricants, it was found ranking for one fluid could vary from third to eighth, depending on the metal/moisture condition.

Test series to investigate corrosion-deposition phenomena in relation to neutralization number limit were performed for selected lubricants and conditions. Magnesium corrosion was generally seen to accelerate in later test hours, beyond the neutralization number limit. Use of the neutralization number limit as the criterion for test termination would have resulted in the absence of significant metal corrosion for all test series except those of O-67-7 This lubricant showed no consistent relationship between corrosion and the neutralization number limit. Deposition trends varied with lubricant type and indicated essentially no effect for the extent of lubricant degradation as measured by neutralization number limit.

Thermal stability experiments with four lubricants showed a much greater spread among the fluids with respect to temperature capability. Contrary to the O-C-D test series, moisture demonstrated a slight detrimental effect in thermal stability runs. However, an appreciable influence was shown for the presence of a seven-metal specimen set. Metals significantly reduced lubricant temperature tolerance and, for two lubricants, it was determined that magnesium exerted the major effect. It is conjectured that acid constituents generated through thermal breakdown are rapidly consumed by reaction with magnesium, thereby affecting neutralization number performance criteria. The products of reaction likewise affected the occurrence of viscosity breakpoints.

In general, neither moisture nor metals noticeably altered deposit formation in the thermal stability tests.

APPENDIX I

TEST METHOD FOR CORROSIVENESS AND OXIDATIVE STABILITY OF AIRCRAFT TURBINE ENGINE LUBRICANTS

1. SCOPE

1.1 This method is used for testing aircraft turbine engine lubricants (synthetic lubricants) to determine their ability to resist oxidative degradation and the tendency to corrode various metals. The method specifies two test procedures: Procedure I of 48-hr duration and Procedure II of 96-hr duration.

2. SAMPLE

2.1 Approximately 250 ml of the lubricant to be tested.

3. APPARATUS

3.1 Sample tube, borosilicate glass, standard wall, 51-mm OD, 450 ± 10-mm overall length (see Figure 7).

3.2 Sample tube head, borosilicate glass, ⅀ 71/60 male ground-glass joint with upper surface formed in a dome-shaped contour (see Figure 8).

3.3 Air tube, borosilicate glass (see Figure 9).

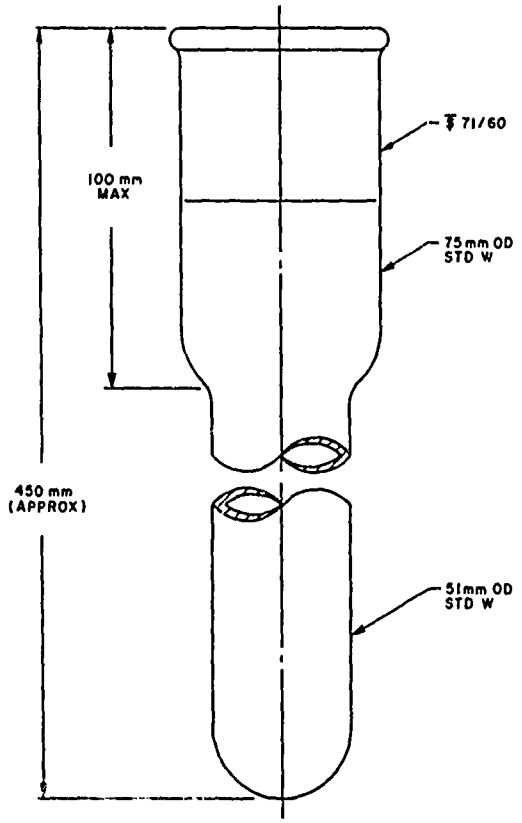

FIGURE 7. SAMPLE TUBE

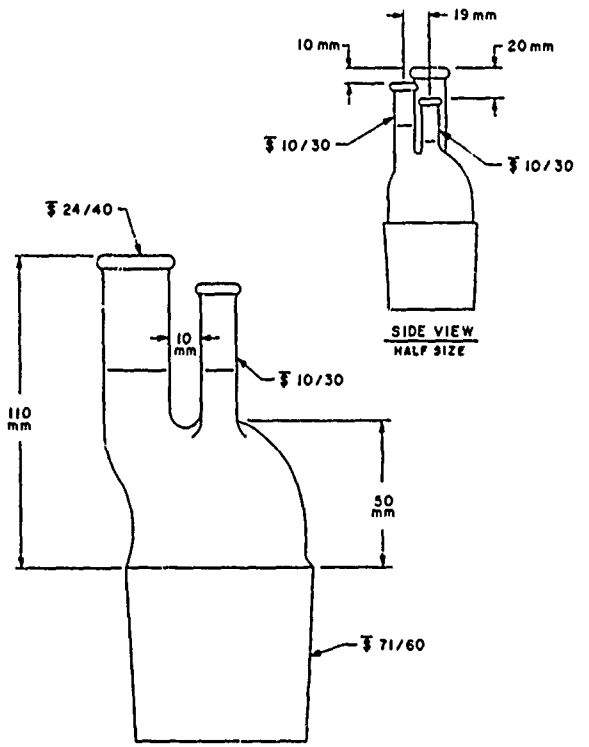

FIGURE 8. SAMPLE TUBE HEAD

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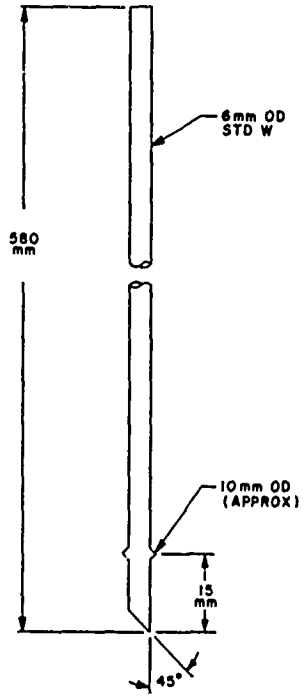

FIGURE 9. AIR TUBE

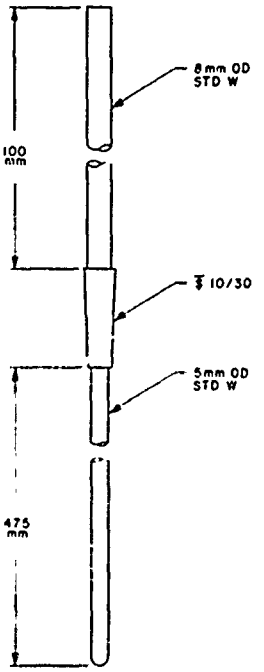

FIGURE 10. THERMOCOUPLE TUBE

3.4 Thermocouple tube, borosilicate glass (see Figure 10). A bare-wire thermocouple is inserted to the bottom of the glass tube and a small volume of high-temperature fluid is injected to facilitate heat transfer. When inserted into the sample tube assembly, the closed end of the thermocouple tube should be at least 10 mm from the sample tube wall.

3.5 Condenser, Allihn type, borosilicate glass, 300-mm water jacket length, with lower end formed as a male T 24/40 joint.

3.6 Spacer, borosilicate glass, standard wall, 9-mm OD, 6-mm length.

3.7 Adapter, Telfon, T 10/18 joint, used to position and seal air inlet tube.

Note 1. The air tube adapter (3.7) may be obtained as Catalog No. K-17980 from:

Kontes Glass Company
Vineland, New Jersey 08360

3.8 Oil sampling device, consisting of a convenient length of 4-mm borosilicate glass tubing with one end fixed by means of a one-hole stopper in a 25-ml filtering flask. The tubing is bent in a U-shape with one leg (sampling side) approximately 600 mm in length. The tube leg attached to the flask may be a much shorter, convenient length.

3.9 Heat medium, constant temperature, capable of maintaining the specified test temperature (sample temperature) within limits of ±1°C (±2°F), and allowing for a sample tube immersion depth of 250 ± 20 mm.

3.10 Flowmeter, capable of an airflow measurement of 10 ± 1 ℓ/hr, calibrated for standard conditions of 70°F and 1 atm.

3.11 Air supply, free of reactive contaminants. For lubricant specifications requiring "dry air" in conducting this test, the dew-point of the air shall be –90°F or below. For lubricant specifications requiring "wet air," the moisture content shall be 10 ± 1 mg water per liter of air.

3.12 Air drier (if required). The precise method of air drying is optional. A satisfactory apparatus is a glass column containing 8 mesh anhydrous calcium sulfate. The column diameter is selected such that the face velocity of the airflow does not exceed 4 ft/min.

3.13 Air moisturizer (if required). The precise method of moisturizing the test air is optional. A satisfactory device is shown in Figure 11. Air enters through a length of 3/8-in. tubing and discharges through a 1-in. diameter diffuser stone. The controlled temperature is that indicated by the thermocouple near the air exit fitting. One heater is operated by an on-off switch and used only for initial preheating. A second heater is in circuit with a variable potential transformer (variac). The variac is adjusted to control the air exit temperature required to give the proper moisture content. The stainless steel tank is insulated over the entire exterior surface and placed within a refrigerator. The air exit fitting and line are well insulated to avoid moisture condensation. The exit line length within the refrigerator is held to a minimum and the downstream portion of the line between the refrigerator and sample tube must not encounter a temperature region lower than the control temperature, or condensation will occur.

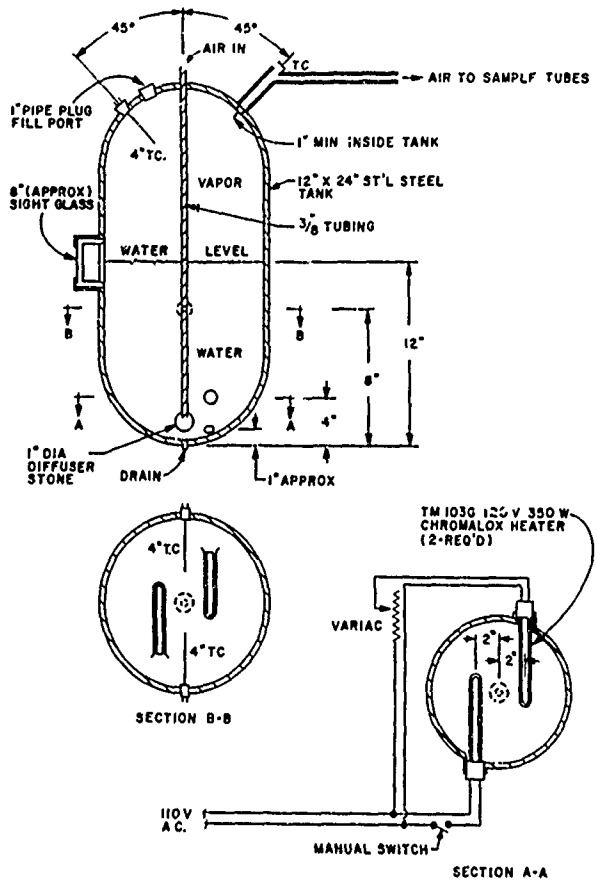

FIGURE 11. AIR MOISTURIZER

Note 2. The stainless steel tank may be obtained as Type G-1W from:

A.C. Tank Company
Post Office Box 389
Burlington, Wisconsin 53105

The apparatus described above will satisfactorily serve as an air moisturizer for several sample tubes, up to a known total of 16 each. At this flow rate (160 ℓ/hr), the following control parameters are typical for achieving a moisture of 10 mg water per liter of air:

Exit air temp	59°F
Water temp	60°F
Refrigerator temp	54°F
Control heater power	<10 watts

The exit air temperature is monitored daily; however, with satisfactory insulation, the variac setting should not require adjustment during a 96-hr test.

The exit air temperature is selected to obtain the desired moisture content. Moisture content may be determined gravimetrically using a U-shaped Schwartz tube with standard taper glass stoppers. The tube is filled with anhydrous calcium sulfate and weighed to the nearest 0.1 mg. The air moisturizer is allowed to temperature equilibrate at the required total airflow. While maintaining the total flow through the moisturizer, the weighing tube is connected to any one of the sample tube air lines. After a 1-hr flow period, the tube weight gain should be 100 ± 10 mg. Any change in the total airflow necessitates recalibration of moisture content since the air velocity through the moisturizer could affect the relative humidity of the air. In the event that a test is performed with a lesser number of sample tubes than that for which originally calibrated, unused flowmeters should be left on to maintain the normal total airflow.

3.14 Balance, analytical, sensitivity 0.1 mg.

3.15 Balance, laboratory, 1500-g capacity, 0.1 g sensitivity.

3.16 Centrifuge, capable of producing a relative centrifugal force of 840 ± 40.

3.17 Tube, centrifuge, ASTM cone-shaped, 100 ml (see method ASTM D 91).

3.18 Microscope, 20-diameter magnification.

3.19 Bath, electrocleaning, consisting of a 1-ℓ glass beaker, hot piate, and variable dc voltage source capable of supplying a current of 1 amp. A battery eliminator is a satisfactory voltage source.

3.20 Photographic equipment. Selection of equipment and procedures is optional. The equipment noted here is listed as one possible choice of selection:

- View camera, Graflex 4 X 5 Crown Graphic Special, with cable release accessory.
- Lens, Synchro-Compur-P, Xenar 1:4. 7/135.
- Tripod, Davis and Sanford Company, Floating Action Tripod.
- Filter, Kodak Photoflood No. 80B.
- Film holder, Graflex 120 roll, 4 X 5 Graphic.
- Film holder, Polaroid Land Holder No. 500.
- Light stands, two each, Smith-Victor Model CB-1.
- Lamps, two each, Sylvania No. 4 Superflood DXR.

4. MATERIALS

4.1 Metal specimens (one each), washer type, 1/4-in. ID by 3/4-in. OD by 0.032-in. thick, as follows.

- Titanium (AMS 4908).
- Magnesium (QQ-M-44, AZ31B, condition H24).
- Steel, tool, M-50 (AMS 6490).

- Steel, carbon, mild (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5).
- Bronze, silicon (AMS 4616).
- Silver, (MIL-S-13282 (ord), grade A).
- Aluminum (QQ-A-250/4, T-3 or T-4).

4.2 Abrasive paper, silicon carbide or aluminum oxide, 240 and 400 grit.

Note 3. "Wet-or-dry" or "waterproof" cloths or papers, or iron containing abrasives such as natural emery, are not satisfactory.

4.3 Cotton, absorbent.

4.4 Benzene, reagent grade.

4.5 Acetone, reagent grade.

4.6 Cleaning solution, glassware, consisting of 1000 ml conc sulfuric acid and 35 ml saturated sodium dichromate solution (aqueous).

4.7 Nitric acid, conc, reagent grade.

4.8 Solvent, trichloroethylene, MIL-T-27602.

4.9 Carbon remover, glassware, such as Calgon Carb-N-Kleen.

4.10 Solution, metal specimen electrocleaning, aqueous solution of 15 g/ℓ sodium hydroxide and 15 g/ℓ trisodium phosphate.

4.11 Color film, such as Kodak Ektacolor Type S, ASA 100, CPS 120.

4.12 Color film packet, such as Polaroid Polacolor, Type 58, ASA 75, 4 X 5 Land film.

4.13 Photographic background paper, dove grey and white.

5. OPERATING CONDITIONS

5.1 Under normal operating conditions, the test is run continuously for a period of 48 or 96 hr at 10-ℓ/hr airflow. In a 48-hr test, intermediate 20-ml samples are taken at 16, 24, and 40 hr. In a 96-hr test, intermediate 10-ml samples are taken at 16, 24, 40, 48, 64, 72, and 88 hr. During the test period, the oil sample temperature is maintained within ±1°C (±2°F) of the specified test temperature. No specific requirements are made with regard to ambient conditions except that the condenser cooling water be 24° ± 3°C (75° ± 5°F). and the water flow controlled to maintain both the water in and out temperature within this range.

6. PREPARATION FOR TEST

6.1 Perform all necessary calibrations of thermocouples, flowmeters, etc.

6.2 Turn on heat medium and bring to a temperature that will maintain the oil sample within ±1°C (±2°F) of the specified test temperature.

6.3 If the test glassware is to be cleaned from a previous run, proceed as follows:

(1) Rinse all glassware items and the air tube adapter with trichloroethylene to remove residual oil, and air dry.

(2) Fill or immerse the sample tube, air tube, and 9-mm glass spacers in carbon remover for a period of 3 to 16 hr to remove carbonaceous deposits. Water rinse after removal.

(3) Subject all glassware items and the air tube adapter to soap and water wash and rinse with distilled water.

(4) Fill or immerse all glassware items with dichromate cleaning solution and soak for 3 to 16 hr.

(5) Remove from the dichromate solution and rinse with warm water, followed by distilled water, and air or oven dry.

(6) Store all items in a dust-free cabinet until required for test. If stored for more than 1 week, the glassware is again rinsed with distilled water and oven dried before use.

6.4 If new glassware is to be used, clean according to paragraph 6.3, omitting steps (1) and (2).

6.5 Assemble the appropriate number of clean sample tubes and accessory items and intermediate sampling containers. Only test oil is used to lubricate ground glass joints during assembly.

6.6 Determine the neutralization number of the original oil sample by method ASTM D 664, using a titration endpoint of pH 11.

6.7 Determine the kinematic viscosity of the original oil sample at 100° and 210°F by method ASTM D 445.

6.8 Collect the required number and types of metal specimens to be used for test.

(1) Clean and prepolish the specimen face surfaces and inner and outer edges using 240-grit abrasive paper. If the specimens are being reused from a previous test, no pitting, etching, or other signs of corrosion should be visible at this point.

(2) Finish with 400-grit paper, removing all marks that may have been left by the previous polishing. The specimens are handled only with forceps or ashless filter paper from this point.

Note 4. As a practical polishing procedure, place a sheet of the abrasive paper on a flat surface and rub the specimen against the paper with longitudinal strokes, holding the specimen with ashless paper. Do not use the same sheet of abrasive paper for polishing different metal types.

(3) Cotton swab the specimens with benzene, followed .cetone, using fresh cotton pads until a pad remains unsoiled.

(4) If there is a short delay before weighing, store the specimens under dry benzene.

6.9 As soon as the metal set is polished, weigh each specimen to within 0.1 mg.

6.10 Slide the specimens onto the air tube. The first specimen rests directly on the air tube collar and succeeding specimens are each separated by a 9-mm glass spacer (para. 3.6). Assemble the metals on the air tube in the following order: aluminum (bottom position), silver, bronze, mild steel, M-50 steel, magnesium, titanium (top).

6.11 Place the air tube, with metals, into the sample tube. Position the head on the sample tube with the air tube extending through the center glass joint. Seat the Teflon adapter on the air tube and tighten the gland. Insert the thermocouple tube and weigh the entire assembly to the nearest 0.1 g.

6.12 Add 200 ± 2 ml of oil to the sample tube, reweigh the assembly, and determine weight of sample added.

7. START OF TEST

7.1 Position the sample tube in the heat medium to an immersion depth of 250 ± 20 mm.

7.2 Insert the Allihn condenser and start the water flow.

7.3 After a 15-min warmup period, connect the air supply and adjust the flow rate to 10 ± 1 ℓ/hr. Begin counting test time from this point.

7.4 Perform adjustment of the heat medium temperature such that the oil sample temperature is held within 1°C (2°F) of the required test value.

8. TEST OPERATION

8.1 Verify sample temperature and airflow rate just prior to each intermediate sampling time.

8.2 Sample the test oil according to the following schedule:

Procedure I, 20-ml sample	Procedure II, 10-ml sample
16	16
24	24
40	40
48 hr	48
	64
	72
	88
	96 hr (20 ml)

8.3 Perform both intermediate and final sampling by withdrawing the thermocouple tube and inserting the 4-mm tube attached to a filtering flask. By means of a rubber bulb, exert a slight suction at the flask tube and draw the oil to a premarked level. Perform the sampling without interrupting the airflow or removing the sample tube from the heat medium.

8.4 Record the total weight of all samples removed during test.

8.5 Examine all samples for viscosity at 100° and 210°F and neutralization number.

Note 5. Due to the reduced intermediate sample volume available with Procedure II, viscosity measurement is made using the semi-micro viscometers listed in method ASTM D 445. In addition, it may be necessary to determine neutralization number using a titration sample size less than that required by method ASTM D 664.

8.6 Using Procedure I, terminate the test at 48 hr. With Procedure II, the test is terminated at 96 hr.

9. TERMINATION AND EVALUATION

9.1 After withdrawing the final sample, shut off the airflow and condenser water and remove the condenser.

9.2 Immediately remove the sample tube assembly from the heat medium, wipe the tube exterior, and weigh the assembly to the nearest 0.1 g. Compute the percentage of oil weight loss as follows:

$$\text{Percent Loss} = \frac{W_2 - (W_3 + W_4)}{W_2 - W_1} \times 100$$

where:

W_1 = Weight of tube assembly

W_2 = Weight of tube assembly plus oil before test

W_3 = Weight of tube assembly plus oil after test

W_4 = Weight of accumulative sample removed

9.3 Remove the thermocouple tube and sample tube head.

9.4 Remove the air tube with metal specimens. Rinse with benzene and carefully slide the specimens off the tube onto a clean absorptive surface.

Note 6. If processing of the specimens is to be delayed, they may be stored under dry benzene.

9.5 Drain the test oil from the tube into a clean glass container. Invert the sample tube and allow to drain for a minimum of 16 hr.

9.6 Rinse the metal specimens, individually, in benzene followed by acetone to remove residual oil. Swab the specimens with benzene-wetted cotton pads until clean pads are noted. Rinse with clean benzene and acetone, air dry, and weigh to within 0.1 mg.

9.7 If, at this point, there are visible carbon deposits remaining on the specimens, they are electrocleaned. The individual specimens, *except aluminum*, are cathodically cleaned in hot (170° to 190°F) electrocleaning solution for a period of 15 to 30 sec at a current density of 0.5 amp/in.^{2} Remove from the bath, rinse in tap water, and cotton swab to remove loose deposits. (Repeat the electrocleaning step, as necessary, to remove all deposits.) Rinse the specimens in acetone, air dry, and reweigh.

9.8 Soak the aluminum specimen in conc nitric acid for 15 min, then water rinse and process as described in paragraph 9.7, but omitting the electrocleaning step.

Note 7. If metal types other than those cited herein are used, the compatibility of the electrocleaning procedure with metal composition should be determined and, if applicable, other appropriate procedures used.

9.9 Examine the metal specimens by microscope at 20X magnification. Record evidence of pitting, etching, color, etc.

9.10 Determine viscosity at 100° and 210°F and neutralization number on the final 20-ml sample taken at end of test.

9.11 Using a representative portion of the bulk oil sample (para 9.5), centrifuge a 25-ml aliquot for 1 hr at a relative centrifugal force of 840 ± 40. Note the volume of solid or semisolid sludge obtained, estimating to 0.01 ml where possible. Record the percentage volume of sludge.

9.12 Following the minimum tube drain period of 16 hr, a color film exposure of the sample tube is taken and printed on 4 X 5-in. glossy paper. Position the camera such that the major film dimension parallels the major tube dimension. A maximum of four tubes per exposure may be included. With multiple-tube exposures, the 4 X 5-in. prints are cut in sections and each tube photograph attached to its corresponding test report data sheet. The photographic procedure is optional. The following procedure is based on the use of equipment and materials, also optional, listed previously:

(1) Place the inverted sample tube on a suitable stand or table which is covered with a sheet of dove grey paper. Also cover the vertical background with white paper at a distance of approximately 10 to 12 in. behind the tube.

(2) To reduce light glare, position the photoflood lamps on either side and directly overhead of the sample tube, with the lamps pointed downward.

(3) The camera is positioned approximately 40 in. (lens to objective) from the tube, and tilted at a slight angle below horizontal.

(4) A color Polaroid exposure is first taken to verify camera focus, position, and aperture. In addition, this photograph provides insurance in the event of loss of the roll film exposure during handling and processing. For the Polaroid exposure, typical camera settings are f 1:8 aperture and 1/10 sec shutter speed.

(5) Without disturbing camera position or focus, replace the Polaroid film adapter with the roll film adapter. With the Ektacolor Type S film, typical camera settings are f 1:16 aperture and 1/10 sec shutter speed.

Note 8. By inspection it is seen that the field of view for the roll film adapter is somewhat less than that outlined by the camera ground-glass viewer. To facilitate positioning, it is recommended that the smaller field be inscribed on the camera viewer, and that the Polaroid exposure be made within this field to avoid repositioning the camera between the two exposure types.

10. REPORT OF RESULTS

10.1 Report kinematic viscosity, expressed in centistokes, for original and all test oil samples at 100° and 210°F. Report percentage change from original viscosity for all intermediate and final samples at 100° and 210°F.

10.2 Report the change from original neutralization number for all intermediate and final samples, expressed in mg KOH/g. Report both the initial and change in neutralization number a negative value represents a neutralization number decrease.

10.3 Report volume percent of sludge in oil obtained by centrifuging.

10.4 Report weight percent of oil loss during test.

10.5 Report the weight change of each metal specimen from the initial, expressed in mg/cm^2, calculated to the nearest 0.1 mg/cm^2. Specimen area is based on the top and bottom surfaces; edges are ignored.

10.6 Report the color and appearance of the metal specimens after cleaning. Report any pitting, etching, or other corrosion observed either without magnification, or with 20X magnification.

10.7 Submit color photograph of test sample tube with report of results.

10.8 Report test conditions, and any irregularities or deviations from required test procedures and conditions.

APPENDIX II

TEST DATA SUMMARY TABLES

TABLE XVI. SUMMARY OF O-C-D TEST RESULTS ON O-66-11

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal(a) attack	Sludge, vol %	Deposit rating Revised	Deposit rating Light meter		BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
374	C	Dry	96	69	19.25	Mg	None	8	—	63	54	0.45	62	430-1
374	D	Wet	96	59	21.2	Mg	0.2	5	—	42	30	0.66	42	431-1
383	F	Wet	48	18	15.22	None	None	0	—	32	20	0.68	30	451-1
↑	F	Wet	96	102	23.2	Mg	Trace	0	5	28	19	0.62	26	471-1
	F	Wet	96	101	23.2	Mg	Trace	0	5	28	19	0.60	26	471-2
	F	Wet	96	111	26.1	Mg, Fe+	Trace	0	5	29	19	0.58	27	471-3
	F	Wet	96	102	26.3	Mg	Trace	0	5	29	19	0.58	27	471-4
	F	Wet	96	108	24.3	Mg	Trace	0	5	31	20	0.58	29	482-1
	F	Wet	96	86	26.8	Mg	Trace	0	5	32	20	0.58	29	482-2
	F	Wet	96	88	28.0	Mg	Trace	0	6	30	19	0.58	28	482-3
↓	F	Wet	96	88	24.5	Mg	Trace	0	5	31	20	0.58	29	482-4
383	F	Dry	96	116	23.0	Mg	None	0	2	30	18	0.50	27	486-1
392	C	Wet	72	36	32.8	Cu, Mg	Trace	—	—	41	30	0.80	39	420-2
↑	C	Dry	96	154	29.7	Cu, Mg	Trace	29	—	24	21	0.56	28	412-2
	D	Wet	96	721	24.3	Bz, Mg	0.2	—	—	28	16	0.60	24	424-2
	F	Wet	13	2	0.44	None	None	10	—	13+	13+	—	—	442-1
↓	F	Wet	48	26	23.6	Mg	Trace	0	—	24	13	0.94	21	439-2
392	H	Wet	96	80	23.5	Mg, Fe+	Trace	—	—	29	16	0.60	23	422-2
401	A	Wet	48	37	16.71	—	None	0	4	15	<8	—	12	519-1
↑	A	Wet	48	38	16.74	—	None	0	4	15	<8	—	12	519-2
	B	Wet	48	25	20.3	—	Trace	0	5	17	<8	—	13	561-1
	B	Wet	48	23	21.1	—	Trace	0	5	17	<8	—	13	561-2
	B	Dry	48	44	17.91	—	None	—	5	15	<8	—	11	621-1
	B	Dry	48	42	17.87	—	None	—	6	15	<8	—	11	621-2
	C	Wet	48	16	16.06	Cu, Mg	0.4	19	30	28	18	0.55	24	490-1
	C	Wet	48	18	15.82	Cu, Mg	0.5	18	33	28	18	0.61	23	490-2
	C	Wet	48	17	14.78	Cu, Mg	Trace	24	21	27	18	0.50	24	522-2
	C	Wet	48	19	14.99	Cu, Mg	Trace	26	22	26	18	0.50	24	522-3
	C	Wet	48	15	17.38	Cu, Mg	0.6	26	29	30	17	0.55	23	523-1
	C	Wet	48	17	15.55	Cu, Ag, Mg	0.6	30	28	30	17	0.56	24	523-2
	C	Dry	48	32	16.09	Mg	None	17	—	23	17	0.94	23	457-1
	C	Dry	96	291	34.2	Cu, Mg	Trace	15	6	19	14	1.13	21	489-1
	D	Wet	48	41	18.70	Bz, Mg	Trace	0	4	17	<8	—	13	493-5
	D	Wet	48	37	18.29	Mg	Trace	0	3	17	<8	—	13	493-6
	I	Wet	16	12	3.39	None	None	14	11	16+	<8	—	—	515-1
	I	Wet	24	0	9.53	None	None	0	4	17	<8	—	16	515-2
	I	Wet	40	26	14.69	Mg	None	11	8	17	<8	—	17	515-3
	I	Wet	48	44	17.05	Mg	None	10	8	17	<8	—	17	515-4
	I	Wet	48	33	23.4	Mg	2	13	21	19	<8	—	17	496-1
↓	I	Wet	48	25	21.4	Mg	0.3	10	14	19	<8	—	18	496-2
401	I	Wet	48	25	24.2	Mg	2	23	17	17	<8	—	17	523-3

TABLE XVI. SUMMARY OF O-C-D TEST RESULTS ON O-66-11 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	E	Wet	48	26	24.2	Mg	2	38	21	17	<8	—	17	523-4
	E	Wet	64	68	19.06	Mg	Trace	10	10	17	<8	—	18	516-1
	E	Wet	64	68	17.53	Mg	Trace	10	11	17	<8	—	17	516-2
	E	Wet	96	198	28.6	Mg	None	9	17	17	<8	—	17	514-1
	E	Wet	96	Semisolid	20.1	Mg, Fe	—	6	4	17	<8	—	17	514-2
	F	Wet	48	25	23.5	Mg	1	7	14	18	<8	—	13	492-5
	F	Wet	48	18	23.1	Mg	0.2	3	6	18	<8	—	13	492-6
	F	Dry	96	340	20.6	Mg, M-50+	Trace	2	4	16	<8	—	12	489-2
	F	Dry	96	441	19.83	Mg, M-50+, Fe+	Trace	2	4	16	<8	—	12	489-3
	G	Wet	48	23	22.3	Ag	Trace	0	6	17	<8	—	12	493-3
	G	Dry	72	51	26.5	None	Trace	2	10	17	<8	—	14	468-1
	H	Wet	48	28	20.9	Mg	1	0	6	18	<8	—	14	495-1
	H	Wet	48	25	22.9	Mg	Trace	4	12	18	<8	—	13	495-2
	I	Wet	48	26	17.83	Mg	0.2	12	9	14	<8	—	18	536-1
	I	Wet	48	28	17.83	Mg	0.2	12	9	16	<8	—	18	536-2
	I	Wet	96	116	25.6	Mg, M-50+, Fe+	Trace	—	20	14	<8	—	15	595-1
	I	Wet	96	370	20.9	Mg, M-50+, Fe+	0.2	—	25	14	<8	—	15	595-2
	I	Dry	48	43	17.30	Mg	None	11	8	17	<8	—	16	580-1
401	I	Dry	48	41	17.35	Mg	None	11	9	17	<8	—	16	580-2
410	C	Wet	48	32	17.76	Cu, Mg	0.6	—	—	16	<8	—	16	421-2
	C	Dry	96	3,559	30.0	Cu, Mg	None	68	—	17	<8	—	14	415-2
	D	Wet	72	10,308	25.3	Bz, Mg	Trace	—	—	16	<8	—	14	425-2
	F	Wet	48	36	26.0	Mg	0.2	5	—	16	<8		13	440-2
410	H	Wet	88	Solid	21.8	Fe, Mg	Solid	—	—	16	<8		14	423-2

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign

TABLE XVII. SUMMARY OF O-C-D TEST RESULTS ON O-67-7

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
374	C	Dry	96	2	20.5	Cu	None	64	—	91	74	2.08	81	430-2
374	D	Wet	96	3	2.82	None	Trace	35	—	96+	96+	—	—	431-2
383	D	Wet	192	1	23.8	Mg	Trace	62	—	192+	133	6.31	108	436-3
383	F	Dry	96	9	2.77	None	Trace	40	46	96+	96+	—	—	486-2
392	C	Wet	72	24	23.0	Cu, Mg	Trace	—	—	57	37	2.34	44	420-3
▲	C	Dry	96	8.147	28.7	Cu, Mg	Semisolid	213	—	42	28	1.50	36	412-3
	D	Wet	96	8	11.79	Mg	Trace	—	—	96+	72	4.10	71	424-3
	F	Wet	16	1	1.39	None	None	28	—	16+	16+	—	—	448-1
	F	Wet	24	2	1.75	None	None	31	—	24+	24+	—	—	448-2
	F	Wet	40	4	2.65	None	None	32	—	40+	40+	—	—	448-3
	F	Wet	48	5	3.20	None	Trace	36	—	48+	48+	—	—	448-4
	F	Wet	64	7	3.81	Mg	Trace	49	—	64+	64+	—	—	448-5
	F	Wet	72	8	4.25	Mg	Trace	52	—	72+	72+	—	69	448-6
	F	Wet	80	9	12.87	Mg	Trace	52	—	80+	65	4.25	62	448-7
	F	Wet	88	10	10.46	Mg	Trace	57	—	88+	75	4.40	69	448-8
	F	Wet	80	9	4.84	Mg	None	56	—	80+	80+	—	63	442-2
	F	Wet	96	11	9.44	Mg	Trace	64	—	96+	80	4.90	72	439-3
	F	Wet	96	10	10.15	Mg	Trace	64	—	96+	73	4.15	72	460-1
	F	Wet	96	11	8.89	Mg	Trace	62	—	96+	76	4.44	72	460-2
	F	Wet	96	11	11.69	Mg	Trace	59	—	96+	73	4.12	72	460-3
	F	Wet	96	7	13.17	Mg	Trace	63	—	96+	73	4.21	71	460-4
	F	Wet	96	10	10.49	Mg	Trace	64	—	96+	73	4.14	72	460-5
	F	Wet	96	11	8.76	Mg	Trace	59	—	96+	83	4.99	70	460-6
	F	Wet	96	8	13.83	Mg	Trace	58	—	96+	72	4.17	71	460-7
	F	Wet	96	28	30.5	Mg	Trace	45	—	71	53	2.95	58	460-8
	F	Dry	72	49	24.4	Mg	Trace	5	—	46	30	1.65	40	463-1
	F	Dry	72	65	24.0	Mg	Trace	2	—	47	32	1.73	43	463-2
	F	Dry	72	69	24.8	Mg	Trace	2	—	46	30	1.65	42	463-3
	F	Dry	72	44	25.2	Mg	Trace	4	—	47	32	1.81	43	463-4
	F	Dry	72	68	23.4	Mg	Trace	6	—	43	29	1.49	38	465-1
	F	Dry	72	52	24.7	Mg	Trace	7	—	45	29	1.49	39	465-2
	F	Dry	72	52	23.6	Mg	Trace	8	—	44	30	1.50	39	465-3
	F	Dry	72	53	22.4	Mg	Trace	7	—	44	29	1.49	38	465-4
	F[b]	Wet	96	10	11.54	Mg	Trace	65	59	96+	78	4.39	68	470-1
	F[c]	Wet	96	10	11.69	Mg	Trace	58	55	96+	76	4.62	67	470-2
	F[d]	Wet	96	5	15.02	Mg	Trace	62	58	96	67	4.15	66	470-3
	F[e]	Wet	96	7	14.21	Mg	Trace	56	52	96+	71	4.41	66	470-4
	F[f]	Wet	96	9	12.27	Mg	Trace	58	55	96+	73	4.35	67	470-5
	G	Wet	96	10	6.28	None	Trace	50	—	96+	96	6.28	67	464-1
	G	Wet	96	10	6.44	None	Trace	55	—	96+	93	6.07	67	464-2
▼ 392	G	Wet	96	10	6.23	None	Trace	48	—	96+	94	5.92	69	464-3

TABLE XVII. SUMMARY OF O-C-D TEST RESULTS ON O-67-7 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
392	G	Wet	96	10	6.54	None	Trace	52	—	96+	93	6.07	68	464-4
▲	G	Wet	96	9	5.98	None	Trace	55	—	96+	96	5.98	70	464-5
▲	G	Wet	96	9	5.91	None	Trace	60	—	96+	96	5.91	70	464-6
▲	G	Wet	96	9	6.05	None	Trace	60	—	96+	95	5.93	70	464-7
▼	G	Wet	96	9	6.06	None	Trace	57	—	96+	95	5.93	70	464-8
392	H	Wet	96	4	16.72	Mg	Trace	—	—	96+	60	3.35	64	422-3
401	A	Wet	16	2	1.32	—	Trace	35	36	16+	16+	—	—	521-1
▲	A	Wet	24	3	1.73	—	Trace	36	43	24+	24+	—	—	521-2
▲	A	Wet	40	7	2.65	—	Trace	47	50	40+	40+	—	—	521-3
▲	A	Wet	48	8	3.11	—	Trace	51	51	48+	48+	—	—	521-4
▲	A	Wet	64	-10	4.49	—	Trace	54	54	64+	63	4.36	60	521-5
▲	A	Wet	72	-12	6.31	—	Trace	60	60	72+	63	4.36	60	521-6
▲	A	Wet	88	-8	13.02	—	Trace	61	66	88+	63	4.36	60	521-7
▲	A	Wet	96	5	14.88	—	Trace	67	70	96+	63	4.36	60	521-8
▲	A	Wet	96	-5	15.06	—	Trace	67	73	95	65	4.70	58	519-3
▲	A	Wet	96	4	16.01	—	Trace	64	72	95	65	4.71	58	519-4
▲	A	Wet	96	7	13.91	—	Trace	59	63	96+	66	4.57	61	526-3
▲	A	Wet	96	7	13.77	—	Trace	64	67	96+	66	4.57	61	526-4
▲	A	Wet	96	-7	14.14	—	Trace	63	67	96+	66	4.57	61	526-5
▲	A	Wet	96	-6	14.59	—	Trace	71	71	96+	66	4.57	61	526-6
▲	A	Wet	96	-5	15.52	—	Trace	68	72	96+	65	4.50	61	526-7
▲	B	Wet	16	-2	1.32	—	Trace	41	38	16+	16+	—	—	570-1
▲	B	Wet	24	-4	1.74	—	Trace	46	40	24+	24+	—	—	570-2
▲	B	Wet	40	7	2.63	—	Trace	50	48	40+	40+	—	—	570-3
▲	B	Wet	48	-8	3.18	—	Trace	57	54	48+	48+	—	—	570-4
▲	B	Wet	64	-11	4.47	—	Trace	56	54	64+	64+	—	59	570-5
▲	B	Wet	72	12	6.80	—	Trace	58	58	72+	64	4.63	58	570-6
▲	B	Wet	88	-7	13.69	—	Trace	61	64	88+	59	4.11	58	570-7
▲	B	Wet	96	-4	16.01	—	Trace	66	70	96+	62	4.42	58	570-8
▲	B	Wet	96	-5	15.51	—	Trace	59	63	96+	62	4.40	59	562-1
▲	B	Wet	96	-5	15.85	—	Trace	64	66	96+	62	4.40	58	562-2
▲	B	Wet	96	3	15.90	—	Trace	61	65	96+	61	4.35	58	569-1
▲	B	Wet	96	-3	15.87	—	Trace	60	66	96+	58	4.01	58	569-2
▲	B	Wet	96	4	15.63	—	Trace	61	67	96+	64	4.61	58	569-3
▲	B	Wet	96	-3	16.17	—	Trace	69	73	96+	62	4.47	58	569-4
▲	B	Wet	96	3	16.27	—	Trace	66	72	96+	62	4.47	58	569-5
▲	B	Dry	16	2	1.11	—	Trace	34	36	16+	16+	—	—	628-1
▲	B	Dry	24	-4	1.42	—	Trace	36	35	24+	24+	—	—	628-2
▲	B	Dry	40	7	2.22	—	Trace	44	40	40+	40+	—	—	628-3
▲	B	Dry	48	9	2.79	—	Trace	46	46	48+	48+	—	—	628-4
401	B	Dry	64	-11	8.03	—	Trace	59	52	64+	48	2.95	54	628-5

TABLE XVII. SUMMARY OF O-C-D TEST RESULTS ON O-67-7 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating Revised	Deposit rating Light meter		BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
401	B	Dry	72	-9	11.47	—	Trace	58	58	72+	51	3.16	56	628-6
↑	B	Dry	88	0.4	17.25	—	Trace	65	64	88+	50	3.12	55	628-7
	B	Dry	96	4	18.76	—	Trace	62	63	92	44	2.64	52	628-8
	B	Dry	96	8	20.9	—	Trace	66	64	89	49	3.05	54	621-3
	B	Dry	96	8	21.3	—	Trace	67	68	88	51	3.02	56	621-4
	B	Dry	96	7	19.87	—	Trace	62	60	89	45	2.78	52	625-1
	B	Dry	96	8	20.4	—	Trace	60	60	89	44	2.70	52	625-2
	B	Dry	96	6	19.80	—	Trace	65	64	90	49	3.04	54	625-3
	B	Dry	96	7	19.65	—	Trace	66	68	90	49	3.04	54	625-4
	B	Dry	96	8	20.2	—	Trace	66	66	89	44	2.66	52	625-5
	C	Wet	48	0.2	21.3	Cu, Mg	Trace	50	49	43	20	2.20	27	490-3
	C	Wet	48	9	22.1	Cu, Mg	Trace	54	55	38	17	1.68	26	490-4
	C	Dry	48	293	16.06	Cu, Mg	Trace	61	—	27	16	1.30	22	457-2
	C	Dry	96	2021	34.3	Cu, Mg	68	150	74	28	12	1.06	22	488-1
	D	Wet	72	64	29.9	Mg	Trace	19	18	41	24	2.04	32	493-7
	D	Wet	72	164	24.5	Mg	Trace	35	36	42	24	2.11	31	493-8
	E	Wet	16	4	1.39	None	Trace	30	35	16+	16+	—	—	516-3
	E	Wet	24	-6	1.92	None	Trace	32	40	24+	24+	—	—	516-4
	E	Wet	40	12	4.85	None	Trace	38	47	40+	28	2.29	37	516-5
	E	Wet	48	-6	13.26	Mg	Trace	55	58	44	26	2.08	32	516-6
	E	Wet	64	11	23.3	Mg	Trace	59	61	46	29	2.39	37	516-7
	E	Wet	72	30	27.0	Mg	Trace	60	66	44	26	2.09	32	516-8
	E	Wet	64	7	26.2	Mg	Trace	66	64	52	32	3.08	38	496-3
	E	Wet	64	30	30.4	Mg	0.6	63	61	43	25	2.19	30	496-4
	E	Wet	72	777	24.2	Mg	Trace	107	79	39	24	2.17	32	506-1
	E	Wet	72	87	26.9	Mg	Trace	52	66	43	28	2.46	34	506-2
	E	Wet	72	341	24.8	Mg	Trace	68	71	43	28	2.34	34	506-3
	E	Wet	72	490	25.6	Mg	Trace	75	75	40	27	2.38	33	506-4
	E	Wet	72	134	26.3	Mg	Trace	62	72	43	28	2.47	34	506-5
	E	Wet	72	484	24.4	Mg	Trace	88	75	42	28	2.47	34	506-6
	E	Wet	72	638	25.0	Mg	Trace	91	74	40	25	2.17	31	512-5
	E	Wet	72	431	26.3	Mg	Trace	61	69	40	25	2.19	31	512-6
	E	Wet	88	1605	31.3	Mg	—	216	89	42	25	2.00	29	522-1
	E	Wet	96	3823	28.7	Mg	0.3	152	83	41	25	2.14	30	514-3
	E	Wet	96	4552	31.7	Mg	0.2	161	81	40	25	2.14	29	514-4
	I	Wet	72	59	29.9	Mg	0.2	35	33	41	26	2.21	33	492-7
	I	Wet	72	102	24.5	Mg	0.2	36	30	41	26	2.21	33	492-8
	I	Dry	96	977	31.3	Mg, M-50+, Fe+	Trace	30	37	41	25	1.60	31	491-2
	I	Dry	96	698	32.1	Mg, M-50+, Fe+	Trace	29	31	42	25	1.60	31	491-3
↓	G	Wet	16	2	1.62	None	Trace	33	32	16+	16+	—	—	467-1
401	G	Wet	24	4	2.13	None	Trace	39	38	24+	24+	—	—	467-2

TABLE XVII. SUMMARY OF O-C-D TEST RESULTS ON O-67-7 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp. °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	G	Wet	40	-7	3.29	None	Trace	45	43	40+	40+	—	—	467-3
	G	Wet	48	-8	3.72	None	Trace	46	43	48+	48+	—	—	467-4
	G	Wet	64	9	5.31	None	Trace	48	44	64+	64+	—	51	467-5
	G	Wet	66	10	5.45	None	Trace	51	47	66+	64	5.23	52	467-6
	G	Wet	72	11	6.91	None	Trace	52	47	72+	64	5.35	51	467-7
	G	Wet	96	7	15.06	None	Trace	56	59	96+	67	5.52	51	466-1
	G	Wet	96	7	15.71	None	Trace	51	55	96+	66	5.54	51	466-2
	G	Wet	96	7	14.63	None	Trace	51	53	96+	66	5.54	52	466-3
	H	Wet	48	4	18.36	Mg	Trace	32	32	41	25	2.18	32	495-3
	H	Wet	48	4	18.55	Mg	Trace	26	29	40	25	2.15	32	495-4
	I	Wet	16	4	1.32	None	None	36	34	16+	16+	—	—	545-1
	I	Wet	24	5	1.75	Mg	None	42	38	24+	24+	—	—	545-2
	I	Wet	40	12	4.84	Mg	None	46	48	40+	30	2.32	38	545-3
	I	Wet	48	7	13.36	Mg	Trace	68	54	46	26	1.95	33	545-4
	I	Wet	64	37	25.0	Mg	0.2	61	50	42	26	1.95	32	545-5
	I	Wet	64	110	22.9	Mg	0.4	74	56	43	25	1.90	31	536-3
	I	Wet	64	17	25.7	Mg	0.2	69	50	47	26	1.95	34	536-4
	I	Wet	64	29	22.8	Mg	Trace	73	58	42	26	2.02	31	544-1
	I	Wet	64	19	25.2	Mg	Trace	84	60	43	26	2.02	31	544-2
	I	Wet	64	9	21.3	Mg	Trace	94	66	47	29	2.30	37	544-3
	I	Wet	64	29	23.0	Mg	Trace	81	53	42	26	2.02	31	544-4
	I	Wet	64	20	24.2	Mg	Trace	72	50	43	26	2.02	31	544-5
	I	Wet	96	1542	33.4	Mg, Bz	—	153	76	42	26	2.12	33	595-3
	I	Wet	96	1615	34.0	Mg	—	192	82	46	27	2.22	35	595-4
	I	Dry	16	-4	1.30	Mg	Trace	—	30	16+	15	1.12	—	591-1
	I	Dry	24	11	4.66	Mg	Trace	—	37	24+	15	1.12	24	591-2
	I	Dry	40	5	14.32	Mg	Trace	—	39	30	15	1.12	24	591-3
	I	Dry	48	19	16.45	Mg	Trace	—	45	30	15	1.12	24	591-4
	I	Dry	48	18	16.56	Mg	Trace	47	41	28	14	0.92	24	580-3
	I	Dry	48	14	17.03	Mg	Trace	48	43	29	14	0.92	26	580-4
	I	Dry	48	15	16.57	Mg	Trace	--	37	31	14	1.92	25	590-1
	I	Dry	48	17	16.01	Mg	Trace	--	35	31	14	1.92	25	590-2
	I	Dry	48	13	16.75	Mg	Trace	--	42	31	14	1.92	26	590-3
	I	Dry	48	20	16.73	Mg	Trace	—	41	31	14	1.92	24	590-4
401	I	Dry	48	19	16.67	Mg	Trace	--	39	30	14	1.92	23	590-5

TABLE XVII. SUMMARY OF O-C-D TEST RESULTS ON O-67-7 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g hr	
								Revised	Light meter					
410	C	Wet	48	537	20.3	Mg, Cu	Trace	---	---	27	<8	0.70	16	421-3
↑	C	Dry	48	2631	17.56	Mg, Cu	14.0	88	---	20	<8	0.64	15	415-3
↕	D	Wet	72	232	34.2	Mg	0.2	---	---	30	12	0.91	22	425-3
↕	F	Wet	11	2	1.45	Mg	None	30	---	11+	11	1.45	---	443-1
↓	I	Wet	48	28	24.7	Mg	Trace	25	---	29	11	1 09	21	440-3
410	H	Wet	72	133	30.6	Mg, Fe+	1.0	---	---	30	11	0.96	22	423-3

(a)Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign
(b)Without Ti
(c)Without steel
(d)Without M-50.
(e)Without Ag
(f)Without Al

TABLE XVIII. SUMMARY OF O-C-D TEST RESULTS ON O-67-8

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
392	C	Wet	96	20	5.11	Cu	Trace	13	—	96+	96+	—	81	453-3
↕	D	Wet	96	18	4.34	None	None	0	—	96+	96+	—	92	453-2
392	F	Wet	96	18	3.75	None	None	0	—	96+	96+	—	—	453-1
401	A	Wet	96	21	3.76	—	None	—	6	96+	96+	—	—	671-1
↑	A	Wet	96	21	3.75	—	None	—	6	96+	96+	—	—	671-2
	B	Wet	96	21	3.78	—	None	—	4	96+	96+	—	—	671-3
	B	Wet	96	26	5.04	—	None	—	3	96+	96+	—	82	671-4
	B	Dry	96	33	5.71	—	None	—	4	96+	96+	—	79	621-5
	B	Dry	96	32	5.85	—	None	—	5	96+	96+	—	78	621-6
	C	Wet	96	42	12.63	Mg, Cu	None	6	—	69	66	3.87	66	455-2
	C	Wet	96	33	8 13	Cu	None	6	12	96+	86	6.53	58	490-5
	C	Dry	96	37	9.09	Cu	None	7	11	96+	63	3.62	66	488-2
	C	Dry	96	39	9.18	Cu	None	3	—	96+	58	3.01	65	457-3
	D	Wet	96	24	5.27	Mg	None	0	—	96+	96+	—	68	455-1
	D	Wet	96	22	4.27	None	None	—	6	96+	96+	—	90	671-5
	E	Wet	96	27	6.64	None	Trace	6	13	96+	91	5.35	73	514-5
	E	Wet	96	26	6.04	None	None	7	12	96+	91	5.00	75	514-6
	F	Wet	96	22	3.86	None	None	—	5	96+	96+	—	—	671-6
	F	Wet	96	21	3.81	None	None	—	4	96+	96+	—	—	671-7
	F	Dry	96	38	6.49	None	None	0	4	96+	94	6.72	69	506-7
	F	Dry	96	36	6.74	None	None	0	4	96+	92	5.85	72	506-8
	G	Wet	96	23	5.06	None	None	4	12	96+	96+	—	68	468-2
	G	Wet	96	23	3.60	None	None	—	5	96+	96+	—	—	671-8
	I	Wet	16	10	1.55	None	None	2	6	16+	16+	—	—	548-1
	I	Wet	24	11	1.93	None	None	3	8	24+	24+	—	—	548-2
	I	Wet	40	13	2.65	None	Trace	6	12	40+	40+	—	—	548-3
	I	Wet	48	15	2.95	None	Trace	6	10	48+	48+	—	—	548-4
	I	Wet	64	16	3.52	None	Trace	9	12	64+	64+	—	—	548-5
	I	Wet	72	19	4.01	None	Trace	8	12	72+	72+	—	72	548-6
	I	Wet	88	21	4.57	None	Trace	9	12	88+	88+	—	78	548-7
	I	Wet	96	26	5 39	None	Trace	5	8	96+	95	5.20	78	548-8
	I	Wet	96	24	5.67	None	None	8	9	96+	91	4.76	80	542-1
	I	Wet	96	24	5.50	None	None	7	10	96+	92	4.94	80	542-2
	I	Wet	96	24	5 70	None	None	9	14	96+	92	4.97	78	546-1
	I	Wet	96	25	5 46	None	None	8	16	96+	96	5.43	79	546-2
	I	Wet	96	24	5 43	None	None	8	14	96+	94	5.04	79	546-3
	I	Wet	96	25	5 88	None	None	8	12	96+	92	5.01	78	546-4
	I	Wet	96	27	6.45	Mg	None	9	10	96+	89	5.24	76	546-5
	I	Dry	16	12	1 39	None	None	—	6	16+	16+	—	—	599-1
	I	Dry	24	14	1.68	None	None	—	7	24+	24+	—	—	599-2
401	I	Dry	40	16	2.10	None	None	—	7	40+	40+	—	—	599-3

TABLE XVIII. SUMMARY OF O-C-D TEST RESULTS ON O-67-8 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Dry	48	18	2.33	None	None	—	7	48+	48+	—	—	599-4
	I	Dry	64	19	3.02	None	None	—	7	64+	64+	—	—	599-5
	I	Dry	72	23	3.93	None	None	—	6	72+	69	3.46	—	599-6
	I	Dry	88	34	6.95	None	None	—	6	88+	67	3.62	70	599-7
	I	Dry	96	34	7.23	None	None	—	6	96+	76	3.91	77	599-8
	I	Dry	96	34	7.46	None	None	0	5	96+	70	3.53	73	580-5
	I	Dry	96	37	8.24	None	None	0	4	96+	67	3.40	71	580-6
	I	Dry	96	33	6.74	None	None	—	5	96+	79	3.97	80	593-1
	I	Dry	96	33	6.87	None	None	—	5	96+	80	4.32	77	593-2
	I	Dry	96	35	7.49	None	None	—	6	96+	78	4.25	76	593-3
	I	Dry	96	33	6.62	None	None	—	6	96+	83	4.43	79	593-4
401	I	Dry	96	30	6.46	None	None	—	7	96+	85	4.20	83	593-5
410	B	Dry	96	45	7.29	—	None	—	6	96+	96+	—	62	638-1
	B	Dry	96	43	7.43	—	None	—	6	96+	96+	—	62	638-2
	C	Wet	96	49	13.33	Mg, Cu	None	12	—	86	54	5.09	39	458-1
	C	Dry	96	66	12.20	Cu	None	11	—	66	43	3.10	49	459-1
	D	Wet	96	29	6.66	Mg	None	0	—	96+	96+	—	47	458-2
	E	Wet	96	44	11.60	None	None	7	21	95	64	5.09	51	509-1
	E	Wet	96	43	10.69	None	None	7	19	94	72	5.90	51	509-2
	F	Wet	96	27	6.64	Mg	None	0	—	96+	96+	—	50	458-3
	F	Dry	72	27	6.01	None	None	0	2	72+	58	3.89	59	502-1
410	F	Dry	72	31	6.80	Ag	None	0	2	72+	55	4.33	52	502-2
419	A	Wet	96	36	6.63	—	None	1	8	96+	91	5.82	51	520-1
	A	Wet	96	35	6.97	—	None	1	6	96+	91	6.14	49	520-2
	B	Wet	96	37	7.60	—	None	3	10	96+	90	6.40	48	559-3
	B	Wet	96	40	7.87	—	None	5	11	96+	91	6.60	50	559-4
	B	Dry	72	41	7.74	—	None	—	6	72+	40	3.59	47	629-1
	B	Dry	72	43	7.49	—	None	—	6	72+	40	3.51	47	629-2
	B	Dry	72	40	7.35	—	None	—	6	72+	43	3.41	47	640-1
	B	Dry	72	38	7.05	—	None	—	8	72+	44	3.55	47	640-2
	B	Dry	72	41	7.49	—	None	—	4	72+	40	3.38	47	640-3
	B	Dry	72	43	7.70	—	None	—	8	72+	38	3.22	43	640-4
	B	Dry	72	44	7.78	—	None	—	6	68	37	3.22	42	640-5
	B	Dry	72	42	7.35	—	None	—	8	72+	38	3.22	43	640-6
	D	Wet	96	73	17.18	Mg, Bz	Trace	4	—	67	50	4.83	38	475-1
	D	Wet	96	51	13.67	Mg	None	12	13	84	74	7.45	34	498-1
	D	Wet	96	43	12.25	Mg	None	13	13	92	76	7.55	34	498-2
	E	Wet	16	12	2.39	None	Trace	9	19	16+	16+	—	—	517-1
	E	Wet	24	14	2.92	None	Trace	8	18	24+	24+	—	—	517-2
	E	Wet	40	18	4.54	None	Trace	9	20	40+	39	4.37	36	517-3
419	E	Wet	48	24	5.98	None	Trace	8	15	48+	41	4.15	39	517-4

TABLE XVIII. SUMMARY OF O-C-D TEST RESULTS ON O-67-8 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
419	L	Wet	64	36	9.32	Mg	Trace	9	20	63	40	4.17	38	517-5
	L	Wet	72	44	10.91	Mg	Trace	10	19	63	40	4.34	37	517-6
	L	Wet	88	66	13.64	Mg	Trace	17	29	64	40	4.30	37	517-7
	L	Wet	96	78	14.97	Mg	Trace	22	36	63	40	4.33	37	517-8
	L	Wet	96	67	15.02	Mg	None	21	34	68	49	5.94	31	501-1
	E	Wet	96	70	15.27	Mg	None	26	38	69	52	5.97	32	501-2
	E	Wet	96	77	15.27	Mg	None	12	24	63	40	4.37	36	507-1
	E	Wet	96	76	15.66	Mg	None	18	32	65	39	4.55	34	507-2
	E	Wet	96	75	15.08	Mg	None	15	34	64	40	4.59	36	507-3
	E	Wet	96	80	15.25	Mg	None	22	38	64	36	4.08	36	507-4
	F	Wet	96	81	13.80	Mg	None	18	33	60	40	4.31	37	507-5
	L	Wet	96	82	15.28	Mg	None	15	28	56	42	4.68	36	507-6
	L	Wet	96	84	15.37	Mg	None	18	32	58	40	4.37	36	507-7
	L	Wet	96	43	10.44	Mg, Ag	Trace	0	—	95	85	7.09	40	474-1
	L	Wet	96	38	10.72	Mg	Trace	1	—	96+	87	7.44	38	474-2
	L	Wet	96	36	9.33	Mg, Ag	Trace	1	—	96+	88	7.51	38	474-3
	L	Wet	96	47	12.60	Mg, Ag	Trace	1	—	84	70	6.10	40	474-4
	F	Wet	96	41	10.11	Mg	None	1	9	96+	81	6.84	38	483-1
	F	Wet	96	42	10.94	Mg	None	1	9	96+	70	6.39	37	483-2
	F	Wet	96	38	8.01	Mg	None	4	18	96+	92	7.32	37	483-3
	F	Wet	96	38	8.52	Mg	None	0	6	96+	91	7.38	38	483-4
	L	Dry	96	66	12.45	Mg	Trace	1	7	90	29	2.73	37	487-1
	I	Dry	96	74	12.68	Mg	None	5	20	57	30	2.75	37	507-8
	G	Wet	96	36	8.64	Ag	Trace	2	—	96+	91	7.50	40	475-2
	G	Wet	96	39	8.50	None	None	4	10	96+	93	8.02	33	479-4
	I	Wet	96	69	15.55	Mg	None	60	41	66	38	4.17	37	541-6
419	I	Wet	96	71	15.42	Mg	None	45	41	66	40	4.29	38	541-7
428	A	Wet	16	12	2.64	—	None	0	4	16+	16+	—	—	534-1
	A	Wet	16	12	2.65	—	None	0	5	16+	16+	—	—	533-1
	A	Wet	24	15	3.19	—	None	0	6	24+	24+	—	—	533-2
	A	Wet	40	20	4.84	—	None	2	8	40+	40+	—	34	533-3
	A	Wet	48	23	5.47	—	None	2	8	48+	48+	—	36	533-4
	A	Wet	64	30	6.61	—	None	3	10	64+	64+	—	37	533-5
	A	Wet	72	36	6.97	—	None	10	10	72+	72+	—	36	533-6
	A	Wet	88	43	8.57	—	None	16	16	88+	88+	—	35	533-7
	A	Wet	96	59	9.28	—	None	18	20	95	92	8.56	37	533-8
	A	Wet	96	51	10.35	—	None	31	26	96+	83	8.07	34	525-1
	A	Wet	96	54	10.08	—	None	29	24	96+	81	7.81	36	525-2
	A	Wet	96	51	9.89	—	None	28	22	96+	90	8.28	34	527-1
	A	Wet	96	50	10.05	—	None	28	24	96+	91	9.06	34	527-2
428	A	Wet	96	54	9.66	—	None	30	22	96+	88	8.09	36	527-3

TABLE XVIII. SUMMARY OF O-C-D TEST RESULTS ON O-67-8 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
428	A	Wet	96	51	9.91	—	None	27	23	96+	91	8.99	34	527-4
	A	Wet	96	51	9.81	—	None	22	19	96+	90	8.59	35	527-5
	A	Wet	96	51	9.66	—	None	23	18	96+	89	8.41	34	527-6
	B	Wet	16	15	2.67	—	None	0	5	16+	16+	—	—	573-1
	B	Wet	24	18	3.42	—	None	0	7	24+	24+	—	—	573-2
	B	Wet	40	23	4.78	—	None	0	5	40+	40+	—	32	573-3
	B	Wet	48	28	5.15	—	None	0	7	48+	48+	—	34	573-4
	B	Wet	64	34	6.97	—	None	3	9	64+	64+	—	34	573-5
	B	Wet	72	38	7.59	—	None	7	11	72+	72+	—	34	573-6
	B	Wet	88	49	9.25	—	None	16	18	88+	88	9.25	34	573-7
	B	Wet	96	56	10.33	—	None	26	28	96+	89	9.05	34	573-8
	B	Wet	96	53	10.22	—	None	19	22	96+	90	8.97	33	564-1
	B	Wet	96	53	10.28	—	None	20	24	96+	89	9.00	33	564-2
	B	Wet	96	56	10.11	—	None	17	18	96+	90	9.13	34	572-1
	B	Wet	96	54	10.22	—	None	18	21	96+	89	9.13	34	572-2
	B	Wet	96	55	10.73	—	None	20	23	96+	88	9.22	34	572-3
	B	Wet	96	54	10.33	—	None	20	26	96+	88	9.18	34	572-4
	B	Wet	96	55	10.53	—	None	21	28	96+	88	9.18	34	572-5
	B	Dry	48	31	6.35	—	None	—	7	48+	28	3.21	34	641-1
	B	Dry	48	32	6.32	—	None	—	7	48+	27	2.99	34	641-2
	D	Wet	72	44	11.91	Mg	None	9	22	72+	40	5.12	30	511-1
	D	Wet	72	50	11.11	Mg	None	12	24	72+	35	4.63	30	511-2
	D	Wet	96	80	16.67	Mg, Bz	Trace	23	28	72	31	4.03	27	476-3
	E	Wet	96	120	17.48	Mg	None	32	34	48	26	4.85	19	505-1
	E	Wet	96	90	16.83	Mg	None	34	38	53	28	4.73	20	505-2
	F	Wet	72	41	10.01	Mg	Trace	2	11	72+	45	5.25	33	511-3
	F	Wet	72	38	7.50	Mg	None	3	11	72+	68	6.95	33	511-4
	F	Wet	96	62	13.60	Mg	Trace	7	18	84	69	7.40	27	476-1
	F	Dry	96	96	15.83	Mg	None	14	16	43	28	3.13	32	499-1
	F	Dry	96	88	15.15	Mg	None	5	15	40	25	2.98	31	505-3
	G	Wet	96	57	10.96	None	Trace	7	18	96+	89	9.71	26	476-2
428	G	Wet	96	56	11.30	None	None	21	32	96+	90	9.74	25	499-2

(a) Defined as a weight change of ± 0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XIX. SUMMARY OF O-C-D TEST RESULTS ON O-67-9

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
374	C	Dry	96	0	1.84	None	Trace	29	--	96+	96+	--	--	434-1
↓	C	Dry	192	133	32.8	None	Trace	63	--	120	105	2.44	112	430-6
↓	D	Wet	96	3	3.97	Mg	Trace	27	--	96+	96+	--	86	434-2
374	D	Wet	192	116	20.5	Mg	0.6	52	--	163	156	4.97	86	431-6
392	C	Wet	96	46	19.35	Mg, Cu	None	--	--	70	57	3.72	59	420-4
↑	C	Dry	96	112	26.0	Cu	Trace	53	--	56	47	1.85	53	412-4
↓	D	Wet	96	32	16.58	Mg	Trace	--	--	83	67	4.50	62	424-4
↓	F	Wet	16	2	1.23	None	None	21	--	16+	16+	--	--	449-1
↓	F	Wet	24	2	1.81	None	None	25	--	24+	24+	--	--	449-2
↓	F	Wet	40	1	2.92	None	Trace	25	--	40+	40+	--	--	449-3
↓	F	Wet	48	2	3.46	None	Trace	26	--	48+	48+	--	--	449-4
↓	F	Wet	64	2	4.62	None	Trace	27	--	64+	64+	--	58	449-5
↓	F	Wet	72	2	5.00	None	Trace	27	--	72+	72+	--	59	449-6
↓	F	Wet	88	5	9.27	Mg	Trace	28	--	88+	76	5.32	59	449-7
↓	F	Wet	90	5	9.16	Mg	Trace	27	--	90+	85	5.92	59	449-8
↓	F	Wet	96	23	16.59	Mg	Trace	26	--	87	75	5.01	59	449-9
↓	F	Wet	74	2	5.82	Mg	Trace	30	--	74+	72	4.74	57	444-1
↓	F	Wet	90	20	16.59	Mg	Trace	33	--	82	74	4.90	60	442-3
↓	F	Wet	96	8	11.76	Mg	Trace	28	--	94	90	5.79	58	439-4
392	H	Wet	96	28	17.99	Mg	Trace	--	--	85	75	5.01	57	422-4
401	A	Wet	16	2	1.32	--	Trace	30	25	16+	16+	--	--	530-1
↑	A	Wet	24	1	1.75	--	Trace	38	33	24+	24+	--	--	530-2
↑	A	Wet	40	0	2.73	--	Trace	40	39	40+	40+	--	--	530-3
↑	A	Wet	48	0	3.33	--	Trace	42	40	48+	48+	--	--	530-4
↑	A	Wet	64	0	4.63	--	Trace	43	42	64+	64+	--	57	530-5
↑	A	Wet	72	2	5.39	--	Trace	42	44	72+	72+	--	59	530-6
↑	A	Wet	88	4	6.62	--	Trace	44	47	88+	88+	--	58	530-7
↑	A	Wet	96	6	7.69	--	Trace	43	47	96+	93	7.32	59	530-8
↑	A	Wet	96	7	7.58	--	Trace	45	48	96+	95	7.49	60	519-5
↑	A	Wet	96	7	7.93	--	Trace	46	49	96+	95	7.84	58	519-6
↑	B	Wet	16	2	1.49	--	Trace	32	30	16+	16+	--	--	575-1
↑	B	Wet	24	1	1.92	--	Trace	32	30	24+	24+	--	--	575-2
↑	B	Wet	40	0	2.82	--	Trace	34	36	40+	40+	--	--	575-3
↑	B	Wet	48	0	3.43	--	Trace	39	38	48+	48+	--	--	575-4
↑	B	Wet	64	0	4.43	--	Trace	41	42	64+	64+	--	59	575-5
↑	B	Wet	72	2	5.10	--	Trace	44	42	72+	72+	--	60	575-6
↑	B	Wet	88	4	6.45	--	Trace	43	41	88+	88+	--	60	575-7
↑	B	Wet	96	5	6.94	--	Trace	46	45	96+	96+	--	60	575-8
↑	B	Wet	96	5	7.59	--	Trace	42	47	96+	92	6.93	58	562-3
↑	B	Wet	96	5	7.51	--	Trace	46	49	96+	92	6.92	58	562-4
401	B	Dry	16	1	1.05	--	Trace	--	26	16+	16+	--	--	637-1

TABLE XIX. SUMMARY OF O-C-D TEST RESULTS ON O-67-9 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	B	Dry	24	0	1.29	—	Trace	—	32	24+	24+	—	—	637-2
▲	B	Dry	40	1	1.90	—	Trace	—	36	40+	40+	—	—	637-3
	B	Dry	48	1	2.40	—	Trace	—	41	48+	48+	—	—	637-4
	B	Dry	64	1	4.61	—	Trace	—	38	64+	54	3.13	60	637-5
	B	Dry	72	3	5.92	—	Trace	—	40	72+	54	3.13	60	637-6
	B	Dry	88	9	7.55	—	Trace	—	46	88+	53	3.08	60	637-7
	B	Dry	96	10	7.85	—	Trace	—	46	96+	59	3.55	63	637-8
	B	Dry	96	11	8.64	—	Trace	—	52	96+	55	3.02	61	621-7
	B	Dry	96	11	8.49	—	Trace	—	50	96+	55	3.02	61	621-8
	C	Wet	96	750	21.6	Mg, Cu	40	71	84	47	35	3.16	40	490-6
	C	Wet	96	126	23.3	Mg, Cu	Trace	73	73	47	35	3.32	40	490-7
	C	Dry	96	106	24.8	Mg, Cu	Trace	51	62	42	28	1.73	36	488-3
	C	Dry	96	124	25.9	Mg, Cu	Trace	60	62	42	28	1.73	36	488-4
	D	Wet	96	57	18.74	Mg	Trace	37	49	76	67	5.32	48	494-1
	D	Wet	96	66	17.21	Mg, Bz	Trace	46	55	68	65	5.16	47	494-2
	E	Wet	16	2	1.30	None	Trace	26	31	16+	16+	—	—	518-1
	E	Wet	24	1	1.82	None	Trace	31	34	24+	24+	—	—	518-2
	E	Wet	40	0	2.84	None	Trace	36	37	40+	40+	—	—	518-3
	F	Wet	48	0	3.64	None	Trace	38	42	48+	47	3.52	—	518-4
	F	Wet	64	2	6.43	None	Trace	45	45	64+	49	3.57	52	518-5
	E	Wet	72	6	8.05	Mg	Trace	50	51	72+	49	3.66	52	518-6
	E	Wet	88	13	10.45	Mg	Trace	54	54	88+	49	3.66	52	518-7
	E	Wet	96	16	10.95	Mg	Trace	55	55	96+	49	3.66	52	518-8
	F	Wet	96	17	12.44	Mg	Trace	36	60	89	59	5.21	47	496-5
	E	Wet	96	18	13.17	Mg	Trace	38	62	89	53	4.75	46	496-6
	F	Wet	96	64	21.2	Mg	Trace	62	60	76	59	5.53	43	500-1
	E	Wet	96	18	12.39	Mg	Trace	61	57	96+	49	3.69	52	508-1
	E	Wet	96	19	12.79	None	Trace	56	53	96+	50	3.69	52	508-2
	E	Wet	96	15	11.69	Mg	Trace	55	55	96+	50	3.65	53	508-3
	E	Wet	96	17	11.99	Mg	Trace	57	55	96+	50	3.69	53	508-4
	E	Wet	96	15	11.29	Mg	Trace	58	56	96+	50	3.69	53	508-5
	E	Wet	96	18	12.24	Mg	Trace	56	60	96+	50	3.69	53	508-6
	E	Wet	96	51	15.26	Mg, M-50+	Trace	36	38	68	65	5.27	45	484-1
	F	Wet	96	51	13.03	Mg, Fe+	Trace	36	32	65	64	5.62	46	484-2
	F	Wet	96	43	12.38	Mg, Fe+, M-50+	Trace	37	37	67	65	5.14	46	484-3
	F	Wet	96	59	13.15	Mg, Fe+, M-50+	Trace	42	40	64	64	5.05	46	484-4
	F	Wet	96	43	19.03	Mg	Trace	43	37	77	73	6.08	47	472-1
	F	Wet	96	57	18.59	Mg	Trace	42	37	70	65	5.34	46	472-2
	F	Wet	96	34	19.15	Mg	Trace	42	40	79	74	6.04	47	472-3
▼	F	Wet	96	39	18.74	Mg	Trace	43	37	78	73	5.85	46	472-4
401	F	Dry	96	12	9.27	None	Trace	40	55	96+	52	2.82	60	491-4

TABLE XIX. SUMMARY OF O-C-D TEST RESULTS ON O-67-9 (Cont'd)

Test conditions				End of test results						100 F vis BP, hr	Neutralization number data			Test no
Temp, F	Metal set	Air	Time, hr	100 F vis change, %	Neut no, mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut no at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Dry	96	11	8.64	None	Trace	68	53	68	53	2.76	62	485-1
	G	Wet	16	2	1.69	None	Trace	25	26	16+	16+	—	—	469-1
	G	Wet	24	1	2.51	None	Trace	27	31	24+	24+	—	—	469-2
	G	Wet	40	1	3.87	None	Trace	32	34	40+	40+	—	—	469-3
	G	Wet	48	1	4.57	None	Trace	36	38	48+	48+	—	43	469-4
	G	Wet	64	2	5.91	None	Trace	37	40	64+	64+	—	44	469-5
	G	Wet	72	3	6.68	None	Trace	41	40	72+	72+	—	43	469-6
	G	Wet	88	5	7.93	None	Trace	39	36	88+	88+	—	43	469-7
	G	Wet	92	7	8.86	None	Trace	42	44	96+	89	8.35	43	469-8
	G	Wet	96	7	8.35	None	Trace	34	38	96+	90	8.02	44	469-9
	G	Wet	96	6	8.80	None	Trace	37	41	96+	91	7.89	46	466-4
	G	Wet	96	6	8.57	None	Trace	40	40	96+	92	7.78	46	466-5
	H	Wet	96	54	15.17	Mg	Trace	42	42	69	63	4.89	46	495-5
	H	Wet	96	48	17.26	Mg	Trace	36	41	74	73	6.11	45	495-6
	I	Wet	16	2	1.46	None	None	31	31	16+	16+	—	—	551-1
	I	Wet	24	1	2.06	None	None	37	33	24+	24+	—	—	551-2
	I	Wet	40	0	3.07	None	Trace	37	36	40+	40+	—	—	551-3
	I	Wet	48	0	3.89	None	Trace	37	40	48+	45	3.42	—	551-4
	I	Wet	64	7	8.89	None	Trace	51	51	64+	48	3.65	50	551-5
	I	Wet	72	13	10.90	Mg	Trace	56	57	72+	48	3.70	50	551-6
	I	Wet	88	29	13.66	Mg	Trace	59	61	76	48	3.69	50	551-7
	I	Wet	96	35	13.88	Mg	Trace	63	60	79	48	3.61	50	551-8
	I	Wet	96	18	11.00	Mg	Trace	61	56	96+	50	3.41	54	536-5
	I	Wet	96	16	10.58	Mg	Trace	60	58	96+	51	3.50	55	536-6
	I	Wet	96	39	15.26	Mg	Trace	78	70	69	45	3.56	48	549-1
	I	Wet	96	41	14.16	Mg	Trace	68	60	69	45	3.56	48	549-2
	I	Wet	96	38	14.90	Mg	Trace	68	64	74	46	3.61	48	549-3
	I	Wet	96	40	15.52	Mg	Trace	70	68	69	45	3.56	48	549-4
	I	Wet	96	46	16.99	Mg	Trace	71	68	69	45	3.56	48	549-5
	I	Dry	16	2	1.14	None	Trace	—	22	16+	16+	—	—	601-1
	I	Dry	24	1	1.41	None	Trace	—	28	24+	24+	—	—	601-2
	I	Dry	40	2	2.36	None	Trace	—	34	40+	40	2.36		601-3
	I	Dry	48	0	4.44	None	Trace	—	40	48+	40	2.23	47	601-4
	I	Dry	64	11	10.60	None	Trace	—	49	60	40	2.30	47	601-5
	I	Dry	72	24	12.95	None	Trace	—	57	60	40	2.25	47	601-6
	I	Dry	72	28	14.69	None	Trace	68	60	53	39	2.41	45	581-1
	I	Dry	72	29	14.57	None	Trace	53	52	53	39	2.41	45	581-2
	I	Dry	72	24	13.55	None	Trace	—	46	55	40	2.25	46	597-1
	I	Dry	72	25	13.61	None	Trace	—	44	55	40	2.25	46	597-2
	I	Dry	72	26	13.63	None	Trace	—	52	55	40	2.25	46	597-3
401	I	Dry	72	30	14.56	None	Trace	—	55	53	40	2.25	46	597-4

TABLE XIX. SUMMARY OF O-C-D TEST RESULTS ON O-67-9 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Dry	72	25	13.72	None	Trace	—	51	55	40	2.25	46	597-5
410	C	Wet	72	159	18.88	Mg, Cu	Trace	—	—	38	21	2.34	28	421-4
▲	C	Dry	96	212	25.2	Mg, Cu	Trace	53	—	32	23	2.00	31	415-4
▼	D	Wet	96	224	23.2	Mg, Bz	Trace	—	—	58	56	5.91	35	425-4
	F	Wet	34	0	4.30	None	None	36	—	34+	26	3.10	32	443-2
	F	Wet	96	92	18.26	Mg	0.2	52	—	66	34	3.75	36	440-4
410	H	Wet	96	110	13.60	Mg, Fe+, S.S.+	Trace	—	—	58	33	3.69	35	423-4

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XX. SUMMARY OF O-C-D TEST RESULTS ON O-67-20

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
374	C	Dry	192	16	1.14	None	None	15	—	192+	192+	—	—	430-5
374	D	Wet	192	12	2.43	None	None	2	—	192+	192+	—	—	431-5
383	C	Dry	192	58	11.52	None	None	13	—	178	171	2.76	176	435-1
383	D	Wet	192	15	4.02	None	None	0	—	192+	190	3.61	192	436-1
392	C	Wet	96	14	2.78	None	None	—	—	96+	96+	—	—	420-5
▲	C	Dry	96	23	3.14	None	None	9	—	94	91	1.26	—	412-5
▲	D	Wet	96	13	2.10	None	None	—	—	96+	96+	—	—	424-5
▼	I	Wet	96	13	2.58	None	None	8	—	96+	96+	—	—	439-5
392	H	Wet	96	14	2.65	None	None	—	—	96+	96+	—	—	422-5
401	A	Wet	96	44	10.49	—	None	7	6	84	77	3.37	81	532-3
▲	A	Wet	96	46	10.55	—	None	7	7	83	77	3.40	80	532-4
▲	B	Wet	96	46	10.93	—	None	6	8	81	75	3.28	78	562-5
▲	B	Wet	96	50	11.03	—	None	3	8	78	74	3.31	77	562-6
▲	B	Dry	96	96	12.10	—	None	—	8	56	50	2.02	58	622-1
▲	B	Dry	96	112	12.95	—	None	—	9	52	49	2.25	55	622-2
▲	B	Dry	96	103	11.81	—	None	—	11	54	49	2.07	55	635-1
▲	B	Dry	96	111	12.03	—	None	—	10	54	49	2.07	55	635-2
▲	B	Dry	96	105	11.78	—	None	—	6	54	49	2.07	55	635-3
▲	B	Dry	96	110	11.71	—	None	—	4	53	49	2.07	55	635-4
▲	B	Dry	96	88	11.44	—	None	—	8	58	52	1.94	60	635-5
▲	B	Dry	96	105	11.99	—	None	—	4	54	49	2.07	55	635-6
▲	C	Wet	96	65	12.72	Mg, Cu	Trace	6	7	76	68	3.42	79	477-1
▲	C	Wet	96	39	9.34	Mg	None	22	25	81	73	3.58	76	490-8
▲	C	Dry	96	71	12.36	Mg, Cu	None	9	11	71	67	2.28	74	491-1
▲	C	Dry	96	82	12.17	Mg, Cu	None	8	11	66	64	2.05	70	497-7
▲	D	Wet	96	18	4.01	None	None	3	7	96+	96	3.97	96	500-3
▲	D	Wet	96	18	4.11	None	None	2	6	96+	96	4.10	95	500-4
▲	I	Wet	96	33	7.97	Mg	None	3	19	85	75	3.81	76	500-2
▲	I	Wet	96	40	9.41	Mg, Bz	None	2	7	80	73	3.20	78	496-7
▲	I	Wet	96	38	9.41	Mg	None	1	6	82	74	3.33	78	496-8
▲	I	Wet	96	18	4.08	None	None	17	—	96+	96+	—	95	441-1
▲	I	Wet	96	46	9.81	Ag	None	—	14	82	74	3.11	78	672-1
▲	I	Dry	96	78	11.03	Mg	None	2	5	53	49	1.88	57	485-2
▲	I	Dry	96	77	9.80	Mg	None	16	12	55	51	2.02	57	491-5
▲	G	Wet	96	19	4.35	None	None	8	11	96+	96+	—	88	468-3
▲	G	Wet	96	19	4.46	None	None	3	10	96+	96+	—	92	477-2
▲	I	Wet	16	8	0.67	None	Trace	8	9	16+	16+	—	—	552-1
▲	I	Wet	24	9	0.96	None	Trace	2	9	24+	24+	—	—	552-2
▲	I	Wet	40	11	1.48	None	Trace	14	14	40+	40+	—	—	552-3
▲	I	Wet	48	12	1.73	None	Trace	14	15	48+	48+	—	—	552-4
401	I	Wet	64	14	2.24	None	Trace	13	12	64+	64+	—	—	552-5

TABLE XX. SUMMARY OF O-C-D TEST RESULTS ON O-67-20 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, F	Metal set	Air	Time hr	100°F vis change, %	Neut no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Wet	72	17	2.97	None	Trace	16	17	72+	72	2.97	—	552-6
↑	I	Wet	88	37	7.69	None	Trace	9	8	77	73	2.90	78	552-7
	I	Wet	96	60	10.12	Mg	Trace	8	8	76	73	2.90	77	552-8
	I	Wet	96	47	9.97	Mg	None	11	7	80	75	2.67	80	536-7
	I	Wet	96	38	8.33	None	None	12	9	86	75	2.69	82	536-8
	I	Dry	16	8	0.66	None	Trace	—	6	16+	16+	—	—	603-1
	I	Dry	24	9	0.94	None	Trace	—	8	24+	24+	—	—	603-2
	I	Dry	40	11	1.31	None	Trace	—	12	40+	40+	—	—	603-3
	I	Dry	48	12	1.41	None	Trace	—	15	48+	48+	—	—	603-4
	I	Dry	64	15	1.98	None	Trace	—	8	64+	64+	—	—	603-5
	I	Dry	72	20	3.17	None	Trace	—	10	72	67	2.10	—	603-6
	I	Dry	88	51	9.11	Mg	None	—	12	67	65	2.24	72	603-7
	I	Dry	96	61	10.27	Mg	None	—	12	73	69	2.42	77	603-8
↓	I	Dry	96	58	9.54	Mg	None	16	10	72	71	2.40	79	581-3
401	I	Dry	96	67	10.75	None	None	16	10	76	71	2.35	78	581-4
410	A	Wet	16	9	1.16	—	None	4	5	16+	16+	—	—	528-1
↑	A	Wet	24	10	1.68	—	None	6	9	24+	24+	—	—	528-2
	A	Wet	40	13	2.55	—	None	12	9	40+	40+	—	—	528-3
	A	Wet	48	17	4.06	—	None	10	10	48	42	2.61	48	528-4
	A	Wet	64	41	8.70	—	None	13	8	48	42	2.60	48	528-5
	A	Wet	72	57	10.25	—	None	8	7	47	41	2.65	47	528-6
	A	Wet	72	57	10.37	—	None	13	12	44	41	2.70	46	524-1
	A	Wet	72	55	10.20	—	None	18	15	47	41	2.77	46	524-2
	A	Wet	72	52	10.02	—	None	13	8	50	46	3.23	50	529-1
	A	Wet	72	56	10.18	—	None	11	9	48	43	2.88	49	529-2
	A	Wet	72	53	9.86	—	None	9	9	51	45	2.98	51	529-3
	A	Wet	72	55	9.94	—	None	13	10	49	43	2.88	49	529-4
	A	Wet	72	56	9.97	—	None	12	9	47	43	2.72	48	529-5
	B	Wet	16	8	1.23	—	None	1	6	16+	16+	—	—	565-1
	B	Wet	24	10	1.64	—	None	4	8	24+	24+	—	—	565-2
	B	Wet	40	13	2.95	—	None	16	15	40+	39	2.77	—	565-3
	B	Wet	48	17	4.60	—	None	17	12	48	41	2.72	46	565-4
	B	Wet	64	41	9.59	—	None	16	12	48	45	3.15	49	565-5
	B	Wet	72	51	10.24	—	None	19	14	53	49	3.15	53	565-6
	B	Wet	72	55	11.11	—	None	6	8	51	43	2.80	49	566-1
	B	Wet	72	40	9.69	—	None	11	15	58	47	3.10	52	566-2
	B	Wet	72	49	10.74	—	None	8	10	54	48	2.97	53	566-3
	B	Wet	72	52	10.53	—	None	11	12	52	45	3.06	50	566-4
↓	B	Wet	72	42	9.56	—	None	8	13	55	47	3.22	51	566-5
410	B	Wet	72	56	10.95	—	None	5	9	52	44	2.85	50	566-6

TABLE XX. SUMMARY OF O-C-D TEST RESULTS ON O-67-20 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
410	B	Wet	72	63	11.33	—	None	7	9	48	42	2.66	47	566-7
	C	Wet	96	96	7.78	Mg, Cu	None	—	—	52	60	3.70	62	421-5
	C	Wet	96	150	14.48	Mg, Cu	None	24	—	43	40	2.21	47	415-5
	D	Wet	96	95	17.44	Mg, Bz	None	—	—	62	57	3.03	62	425-5
	F	Wet	49	14	3.47	None	None	4	—	49+	48	3.07	—	443-3
	F	Wet	96	83	11.39	Mg	None	6	—	53	49	3.12	54	440-5
	F	Wet	96	77	10.62	Mg	Trace	8	—	61	52	3.68	55	473-1
	F	Wet	96	74	10.54	Mg	Trace	7	—	60	51	3.76	53	473-2
	F	Wet	96	69	10.41	Mg	Trace	9	—	58	51	3.55	54	473-3
	F	Wet	96	74	10.88	Mg	Trace	10	—	58	50	3.55	52	473-4
	F	Wet	96	78	10.77	Mg	None	16	17	56	49	3.26	54	481-1
	F	Wet	96	72	10.37	Mg	None	11	12	56	51	3.30	54	481-2
	F	Wet	96	69	10.74	Mg	None	9	12	55	48	3.15	54	481-3
	F	Wet	96	70	10.02	Mg	None	4	9	56	49	3.29	52	481-4
	G	Wet	96	61	10.66	None	None	11	13	64	54	3.44	57	478-1
	G	Wet	96	96	10.57	None	None	—	12	51	48	2.94	53	643-1
	G	Wet	96	110	11.24	None	None	—	10	52	49	3.00	54	643-2
410	H	Wet	96	67	8.43	Mg	None	—	—	60	47	2.73	58	423-5
419	A	Wet	96	167	11.30	—	None	12	10	30	23	2.13	32	520-3
	A	Wet	96	164	11.55	—	None	16	15	30	25	2.09	32	520-4
	F	Wet	28	12	3.13	None	None	15	—	28+	25	2.29	—	445-2
	F	Wet	72	64	10.20	Mg	None	18	—	40	28	2.78	35	445-1
	F	Wet	72	75	9.72	Mg	Trace	14	16	33	26	2.00	34	559-1
	F	Wet	72	93	9.20	Mg	Trace	14	14	27	25	2.23	32	559-2
	G	Wet	96	129	10.99	Ag	Trace	5	—	32	26	2.40	34	475-3
419	G	Wet	96	146	11.79	None	None	27	30	37	26	2.64	33	479-1

(a) Defined as a weight change of ±0.20 mg/cm or more. A weight increase is indicated by a "+" sign.

TABLE XXI. SUMMARY OF O-C-D TEST RESULTS ON O-68-7

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
392	C	Wet	96	19	6.33	None	Trace	2	---	96+	96+	---	62	453-6
↓	D	Wet	96	19	6.22	None	None	2	---	96+	96+	---	59	453-5
392	F	Wet	96	19	6.13	None	None	3	---	96+	96+	---	58	453-4
401	A	Wet	96	26	7.09	---	None	0	2	96+	93	6.65	48	526-1
↑	A	Wet	96	26	6.96	---	None	0	3	96+	94	6.70	48	526-2
	A	Wet	96	26	6.56	---	None	0	2	96+	96+	---	50	538-1
	A	Wet	96	25	6.74	---	None	0	2	96+	96	6.74	50	538-2
	A	Wet	96	26	6.67	---	None	0	2	96+	96+	---	50	538-3
	A	Wet	96	25	6.58	---	None	0	2	96+	96	6.58	50	538-4
	A	Wet	96	25	6.51	---	None	0	3	96+	96+	---	50	538-5
	A	Wet	96	25	6.65	---	None	0	3	96+	96+	---	50	538-6
	B	Wet	96	28	7.86	---	None	0	4	96+	93	7.27	46	562-7
	B	Wet	96	27	7.47	---	None	0	4	96+	96+	---	46	562-8
	B	Wet	96	28	7.32	---	None	0	3	96+	96	7.32	47	576-1
	B	Wet	96	27	7.12	---	None	0	5	96+	96+	---	47	576-2
	B	Wet	96	26	7.06	---	None	0	5	96+	96+	---	47	576-3
	B	Wet	96	27	7.22	---	None	0	4	96+	96+	---	47	576-4
	B	Wet	96	26	7.21	---	None	0	4	96+	96+	---	47	576-5
	B	Wet	96	28	7.12	---	None	0	5	96+	96+	---	47	576-6
	B	Dry	96	72	15.09	---	None	---	4	53	40	3.33	44	622-3
	B	Dry	96	67	14.17	---	None	---	3	54	40	3.33	43	622-4
	C	Wet	88	50	17.49	Mg	0.2	2	6	67	57	5.08	43	492-1
	C	Wet	96	76	18.48	Mg	None	6	---	68	62	5.95	44	455-4
	C	Dry	72	47	14.56	None	Trace	1	---	54	49	3.34	53	457-4
	C	Dry	96	106	21.2	None	None	11	8	53	47	3.41	50	488-5
	D	Wet	96	29	8.10	None	None	6	0	96+	93	7.48	41	455-3
	D	Wet	96	27	7.51	None	None	0	5	96+	96+	---	35	494-3
	E	Wet	96	34	13.33	Mg, Ag	None	0	4	92	84	7.28	44	497-1
	E	Wet	96	32	11.87	Mg, Ag	None	1	5	94	84	7.20	44	497-2
	F	Wet	96	38	14.16	None	None	0	3	90	81	6.70	48	508-7
	E	Wet	96	36	13.32	None	None	0	4	90	82	6.85	48	508-8
	F	Wet	96	45	14.93	None	None	0	4	86	73	6.05	46	512-1
	F	Wet	96	52	15.94	None	None	0	5	79	72	6.09	46	512-2
	E	Wet	96	55	17.17	Mg	None	0	4	79	73	6.06	48	512-3
	E	Wet	96	51	16.10	None	None	0	5	81	74	6.03	47	512-4
	F	Wet	96	30	8.29	Mg	Trace	0	3	96+	96+	---	36	477-3
	F	Wet	96	29	6.96	Ag	None	---	3	96+	96+	---	47	672-2
	F	Dry	96	82	16.04	Mg	None	0	3	42	27	2.26	36	485-3
	F	Dry	96	83	15.65	Mg, Ag	None	0	3	40	23	1.95	35	491-6
↓	G	Wet	96	31	8.17	None	None	1	7	96+	96+	---	40	468-4
401	G	Wet	96	28	7.93	Ag	None	1	4	96+	96+	---	38	477-4

TABLE XXI. SUMMARY OF O-C-D TEST RESULTS ON O-68-7 (Cont'd)

Test conditions				End of test results						100 F vis BP, hr	Neutralization number data			Test no.
Temp, F	Metal set	Air	Time, hr	100 F vis change, %	Neut no mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Wet	96	39	13.28	None	None	0	2	88	76	5.43	54	537-1
	I	Wet	96	43	13.75	None	None	0	3	86	76	5.25	54	537-2
	I	Wet	96	50	14.54	None	None	0	3	80	72	5.51	51	553-1
	I	Wet	96	53	15.72	Mg	None	0	4	76	70	5.42	51	553-2
	I	Wet	96	40	13.91	None	None	0	3	90	79	6.01	51	553-3
	I	Wet	96	44	13.94	None	None	0	5	84	72	5.54	51	553-4
	I	Wet	96	26	8.31	None	None	0	5	96+	89	6.80	54	553-5
	I	Wet	96	41	13.43	None	None	0	4	88	72	5.48	51	553-6
	I	Dry	72	54	15.20	None	None	0	5	49	42	3.12	46	581-5
	I	Dry	72	56	14.99	None	None	0	5	48	41	3.10	46	581-6
	I	Dry	72	49	14.26	None	None	---	3	54	43	3.30	48	615-1
	I	Dry	72	39	13.47	None	None	---	3	59	47	3.63	50	615-2
	I	Dry	72	50	14.76	None	None	---	2	55	43	3.31	47	615-3
	I	Dry	72	53	15.27	None	None	---	3	52	41	3.10	46	615-4
	I	Dry	72	50	14.37	None	None	---	3	52	41	3.08	45	615-5
401	I	Dry	72	57	15.42	None	None	---	3	49	40	3.00	45	615-6
410	A	Wet	96	58	11.50	---	None	0	6	76	<16	---	31	524-3
	A	Wet	96	58	11.88	---	None	0	5	75	<16	---	30	524-4
	A	Wet	96	63	11.29	---	None	0	4	69	<16	---	30	543-1
	A	Wet	96	61	11.33	---	None	0	3	70	<16	---	30	543-2
	A	Wet	96	64	11.71	---	None	0	3	68	<16	---	30	543-3
	A	Wet	96	64	11.66	---	None	0	4	74	<16	---	30	543-4
	A	Wet	96	54	10.78	---	None	0	3	71	<16	---	30	543-5
	A	Wet	96	60	11.11	---	None	0	4	69	<16	---	30	543-6
	C	Wet	72	64	18.07	Mg	Trace	9	0	41	30	3.65	32	458-4
	C	Dry	48	52	13.94	None	None	0	---	28	19	2.00	27	459-2
	D	Wet	96	61	14.00	Mg	None	2	---	77	64	8.14	27	458-5
	I	Wet	96	61	14.68	Mg	None	2	---	76	64	6.05	27	458-6
	I	Wet	96	71	15.47	Mg, Ag	Trace	0	---	69	60	7.50	26	473-5
	I	Wet	96	77	15.79	Mg, Ag	Trace	1	---	66	54	7.12	26	473-6
	I	Wet	96	64	14.02	Mg, Ag	Trace	0	---	73	65	8.13	27	473-7
	I	Wet	96	73	15.40	Mg, Ag	Trace	0	---	68	57	7.25	26	473-8
	I	Wet	96	65	14.79	Mg	None	4	10	66	49	6.71	26	478-3
	I	Wet	96	71	15.49	Mg, Ag	None	3	8	67	58	7.25	26	481-5
	I	Wet	96	71	15.35	Mg, Ag	None	3	8	70	65	7.57	27	481-6
	I	Wet	96	64	14.60	Mg, Ag	None	3	9	71	60	7.40	26	481-7
	I	Wet	96	64	14.05	Mg	None	1	6	74	59	7.07	26	481-8
	G	Wet	72	31	8.62	Ag	None	0	3	72+	71	8.48	27	502-3
410	G	Wet	96	50	11.66	Ag	None	0	3	94	73	9.06	25	478-2
419	A	Wet	96	109	13.44	---	None	2	9	35	<8	---	20	520-5
419	A	Wet	96	106	13.28	---	None	0	6	37	<8	---	20	520-6

TABLE XXI SUMMARY OF O-C-D TEST RESULTS ON O-68-7 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp. °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. No., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
419	F	Wet	96	90	10.96	Mg	None	18	16	48	<8	—	18	498-3
▲	F	Wet	96	89	13.98	Mg	Trace	20	20	48	<8	—	18	498-4
▼	F	Wet	96	107	12.71	Mg, Ag	None	14	20	42	<8	—	14	479-3
	G	Wet	96	101	14.28	Ag	Trace	2	5	45	<8	—	18	475-4
	G	Wet	96	97	13.46	Ag	None	1	6	47	<8	—	15	479-2
419	G	Wet	96	92	12.91	None	Trace	21	21	48	<8	—	17	498-5
428	G	Wet	96	161	15.83	None	None	21	22	16	<8	—	10	499-3

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XXII. SUMMARY OF O-C-D TEST RESULTS ON O-68-17

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
374	C	Dry	96	57	25.4	Mg, Cu	None	3	—	65	64	2.05	70	430-3
374	D	Wet	96	4	5.00	None	None	1	—	96+	96+	—	74	431-3
383	D	Wet	192	75	44.0	Mg	Trace	3	—	157	151	8.94	—	436-2
392	C	Wet	72	54	29.7	Mg, Cu	None	—	—	42	22	3.10	27	420-6
↑	C	Dry	96	286	43.9	Mg, Cu	Trace	34	—	41	26	2.23	33	412-6
	D	Wet	96	6	16.42	Mg	None	—	—	96+	88	8.40	42	424-6
	F	Wet	16	1	2.13	None	None	0	—	16+	16+	—	—	450-1
	F	Wet	24	2	2.87	None	None	0	—	24+	24+	—	—	450-2
	F	Wet	40	3	3.99	None	None	0	—	40+	40+	—	—	450-3
	F	Wet	48	3	4.40	None	None	0	—	48+	48+	—	40	450-4
	F	Wet	64	2	5.58	None	None	0	—	64+	64+	—	40	450-5
	F	Wet	72	18	17.25	Mg	Trace	0	—	67	58	5.46	40	450-6
	F	Wet	81	26	20.3	Mg	Trace	0	—	67	65	5.74	40	450-7
	F	Wet	88	5	8.18	Mg	Trace	0	—	88+	82	7.36	40	450-8
	F	Wet	81	4	6.84	Mg	None	0	—	81+	81+	—	37	442-4
	F	Wet	96	6	8.20	Mg	Trace	0	—	96+	81	7.11	36	439-6
	F	Wet	96	4	7.34	None	Trace	0	—	96+	96+	—	43	452-1
	F	Wet	96	4	7.27	Mg	Trace	0	—	96+	96+	—	45	452-2
	F	Wet	96	37	25.6	Mg	Trace	3	—	77	74	5.81	45	452-3
	F	Wet	96	5	7.47	Mg	Trace	0	—	96+	96+	—	44	452-4
	F	Wet	96	5	7.50	None	Trace	0	—	96+	96+	—	43	452-5
	F	Wet	96	80	28.5	Mg	Trace	6	—	74	65	5.50	42	452-6
	F	Wet	96	5	8.95	None	Trace	0	—	96+	94	8.75	38	452-7
	F	Wet	96	5	8.15	None	None	0	—	96+	96+	—	41	452-8
	F	Dry	96	10	9.34	None	None	2	—	96+	66	2.94	72	462-1
	F	Dry	96	10	9.70	None	None	0	—	96+	75	3.60	78	462-2
	F	Dry	96	15	12.53	None	None	0	—	96+	65	3.10	69	462-3
	F	Dry	96	14	12.56	None	None	0	—	96+	66	3.25	70	462-4
	F	Dry	96	11	10.16	None	None	0	—	96+	66	3.05	70	462-5
	F	Dry	96	13	11.69	None	None	0	—	96+	65	3.14	68	462-6
	F	Dry	96	10	9.19	None	None		—	96+	65	3.11	70	462-7
	F	Dry	96	11	10.48	None	None	1	—	96+	66	2.93	70	462-8
	G	Wet	96	5	7.55	None	Trace	0	—	96+	96+	—	41	461-1
392	H	Wet	96	22	20.2	Mg	None	—	-	89	72	6.90	32	422-6
401	A	Wet	96	5	7.40	-	None	—	8	96+	96+	—	46	672-3
↑	A	Wet	96	5	7.39	—	None	—	8	96+	96+	—	46	672-4
	B	Wet	96	5	7.15	—	None	—	4	96+	96+	—	46	672-5
	B	Wet	96	5	7.34	—	None	—	4	96+	96+	—	46	672-6
	B	Dry	96	24	17.72	—	None	—	7	96+	49	3.35	52	622-5
	B	Dry	96	24	17.87	—	None	—	8	96+	49	3.65	51	622-6
401	B	Dry	96	15	12.00	—	None	—	4	96+	53	3.35	56	632-1

TABLE XXII SUMMARY OF O-C-D TEST RESULTS ON O-68-17 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	B	Dry	96	20	14.99	—	None	—	5	96+	50	3.31	54	632-2
	B	Dry	96	20	15.42	—	None	—	7	96+	50	3.33	53	632-3
	B	Dry	96	23	16.17	—	None	—	11	96+	50	3.31	53	632-4
	B	Dry	96	19	14.38	—	None	—	12	96+	51	3.10	54	632-5
	B	Dry	96	50	27.0	—	None	—	42	56	41	3.10	44	632-6
	C	Wet	48	21	20.9	Mg, Cu	Trace	2	9	32	<8	—	22	492-2
	C	Wet	48	23	20.1	Mg, Cu	Trace	4	10	38	<8	—	21	492-3
	C	Dry	96	1444	49.0	Mg, Cu	80	34	16	28	<8	—	23	488-6
	C	Dry	96	1044	46.7	Mg, Cu	60	27	14	29	<8	—	23	488-7
	D	Wet	96	6	9.36	Mg	Trace	0	8	96+	85	8.26	35	494-4
	D	Wet	96	97	31.9	Mg	None	8	15	68	64	6.12	35	494-5
	E	Wet	72	43	29.3	Mg	Trace	1	9	53	38	4.63	32	497-3
	E	Wet	72	37	27.9	Mg	Trace	1	7	53	38	4.56	32	497-4
	E	Wet	72	32	22.6	Mg	None	6	12	53	44	4.38	41	510-1
	E	Wet	72	33	22.9	Mg	None	7	12	53	47	4.71	40	510-2
	E	Wet	72	30	22.2	Mg	None	16	30	53	45	4.55	40	510-3
	E	Wet	72	44	26.8	Mg	None	0	6	51	45	4.55	40	510-4
	E	Wet	72	40	25.1	Mg	None	0	7	52	44	4.40	40	510-5
	E	Wet	72	32	23.1	Mg	None	10	25	53	45	4.60	39	510-6
	E	Wet	96	172	40.3	Mg	0.2	15	30	55	46	4.47	42	514-7
	E	Wet	96	102	37.2	Mg	Trace	11	18	55	45	4.34	42	514-8
	F	Wet	88	16	17.94	Mg	Trace	0	4	83	73	6.63	36	493-1
	F	Wet	88	23	22.0	Mg	Trace	0	3	80	72	6.66	35	493-2
	F	Dry	96	32	22.4	Mg	None	8	14	94	41	3.50	43	491-7
	F	Dry	96	24	17.42	None	None	2	12	96+	51	3.65	54	485-4
	G	Wet	96	7	9.94	None	Trace	1	8	96+	93	9.39	35	480-1
	G	Wet	96	7	9.51	None	Trace	0	7	96+	94	9.25	31	480-2
	G	Wet	96	6	9.18	None	Trace	2	9	96+	93	8.54	32	480-3
	G	Wet	96	6	9.28	None	Trace	0	6	96+	91	8.12	32	480-4
	G	Wet	96	6	8.85	None	None	0	8	96+	93	8.20	33	480-5
	G	Wet	96	6	9.50	None	None	1	7	96+	93	9.05	32	466-6
	G	Wet	96	6	10.32	None	None	2	8	96+	89	8.88	32	466-7
	G	Wet	96	7	10.36	None	None	2	8	96+	93	9.86	32	466-8
	H	Wet	96	48	27.8	Mg	Trace	0	5	78	73	7.35	33	495-7
	H	Wet	96	25	23.8	Mg	None	0	5	87	75	7.55	33	495-8
	I	Wet	16	1	2.11	None	None	0	2	16+	16+	—	—	555-1
	I	Wet	24	1	2.63	None	None	0	4	24+	24+	—	—	555-2
	I	Wet	40	2	3.69	None	None	0	5	40+	40+	—	—	555-3
	I	Wet	48	2	4.31	None	None	0	5	48+	48	4.31	45	555-4
401	I	Wet	64	18	15.48	Mg	Trace	2	7	56	47	4.31	44	555-5

TABLE XXII. SUMMARY OF O-C-D TEST RESULTS ON O-68-17 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Wet	72	30	21.6	Mg	Trace	5	9	57	48	4.36	45	555-6
↑	I	Wet	72	33	22.5	Mg	Trace	5	6	53	49	4.59	42	537-3
	I	Wet	72	32	21.8	Mg	Trace	5	7	56	49	4.59	42	537-4
	I	Wet	72	28	21.4	Mg	Trace	2	7	59	49	4.45	44	554-1
	I	Wet	72	37	24.1	Mg	Trace	2	7	52	48	4.45	44	554-2
	I	Wet	72	34	22.2	Mg	Trace	3	11	52	48	4.45	44	554-3
	I	Wet	72	25	19.34	Mg	Trace	18	31	59	49	4.45	44	554-4
	I	Wet	72	29	21.5	Mg	Trace	1	6	59	50	4.47	45	554-5
	I	Wet	96	175	33.8	Mg	Trace	—	28	55	46	4.40	42	595-5
	I	Wet	96	448	36.2	Mg	2	—	32	55	46	4.40	42	595-6
	I	Dry	16	1	1.64	None	None	—	4	16+	16+	—	—	608-1
	I	Dry	24	2	2.21	None	None	—	4	24+	24+	—	—	608-2
	I	Dry	40	2	2.87	None	None	—	5	40+	40+	—	—	608-3
	I	Dry	48	2	3.23	None	None	—	5	48+	48+	—	—	608-4
	I	Dry	64	9	9.96	None	None	—	6	64+	51	3.66	53	608-5
	I	Dry	72	13	12.08	Mg	None	—	7	72+	51	3.34	55	608-6
	I	Dry	88	43	25.2	Mg	None	—	6	75	50	3.50	53	608-7
	I	Dry	96	28	21.1	Mg	None	—	7	90	52	3.46	55	608-8
	I	Dry	72	16	13.96	Mg	None	1	6	72+	45	3.26	49	581-7
	I	Dry	72	14	13.06	Mg	None	3	10	72+	44	3.20	48	581-8
	I	Dry	96	108	37.3	Mg	None	0	7	65	43	3.15	47	583-1
	I	Dry	96	97	37.2	Mg	None	0	5	66	42	3.20	45	583-2
	I	Dry	96	32	23.1	Mg	None	—	5	90	50	3.20	53	606-1
	I	Dry	96	63	29.8	Mg	None	—	6	73	50	3.20	53	606-2
	I	Dry	96	57	29.3	Mg	None	—	4	76	49	3.21	53	606-3
↓	I	Dry	96	20	16.81	Mg	None	—	8	96+	52	3.35	56	606-4
401	I	Dry	96	33	22.7	Mg	None	—	5	89	52	3.35	56	606-5
410	A	Wet	96	9	10.32	—	None	19	17	96+	82	8.06	34	524-5
↑	A	Wet	96	9	10.34	—	None	20	22	96+	82	8.25	35	524-6
	B	Wet	96	8	10.20	—	None	17	18	96+	66	6.66	35	565-7
	B	Wet	96	18	16.24	—	None	22	24	96+	64	6.52	35	565-8
	C	Wet	48	131	20.1	Cu, Mg	0.2	—	—	22	4	0.63	15	421-6
	C	Dry	72	2440	38.7	Cu, Mg	60.0	94	—	23	9	0.85	18	415 6
	D	Wet	96	178	35.2	Mg	Trace	—	—	49	47	6.05	26	425-6
	F	Wet	32	2	4.93	None	None	0	—	32+	32	4.93	25	443-4
↓	F	Wet	72	65	28.6	Mg	Trace	2	—	49	32	5.17	21	440-6
410	H	Wet	96	73	33.8	Mg	Trace	—	—	65	47	6.26	23	423-6
419	A	Wet	16	1	2.96	—	None	0	3	16+	16+	—	—	531-1
↕	A	Wet	24	2	3.97	—	None	0	3	24+	24+	—	—	531-2
	A	Wet	40	3	5 72	—	None	0	4	40+	40+	—	25	531-3
419	A	Wet	48	6	7.35	—	None	1	5	48+	47	7.20	16	531-4

TABLE XXII. SUMMARY OF O-C-D TEST RESULTS ON O-68-17 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
419	A	Wet	64	7	9.17	—	Trace	14	13	64+	45	6.47	24	531-5
	A	Wet	72	9	9.98	—	Trace	18	18	72+	40	5.65	24	531-6
	A	Wet	88	11	12.19	—	Trace	30	28	88+	52	6.87	26	531-7
	A	Wet	96	26	20.4	—	Trace	38	40	96+	40	5.54	25	531-8
	A	Wet	96	14	13.77	—	None	29	28	96+	42	5.70	27	541-1
	A	Wet	96	15	13.97	—	None	21	22	96+	42	5.70	27	541-2
	A	Wet	96	13	13.11	—	None	26	27	96+	47	6.05	27	541-3
	A	Wet	96	24	18.44	—	None	26	30	96+	48	6.15	26	541-4
	A	Wet	96	13	12.86	—	None	29	31	96+	44	5.70	28	541-5
	A	Wet	96	14	14.22	—	None	33	31	96+	44	6.18	23	520-7
	A	Wet	96	14	13.64	—	None	21	25	96+	47	6.05	27	520-8
	B	Wet	16	2	3.39	—	None	0	5	16+	16+	—	—	578-1
	B	Wet	24	2	4.11	—	None	1	5	24+	24+	—	23	578-2
	B	Wet	40	3	5.48	—	None	2	6	40+	40+	—	25	578-3
	B	Wet	48	4	6.60	—	None	5	9	48+	44	6.06	24	578-4
	B	Wet	64	12	12.00	—	None	7	12	64+	40	5.56	25	578-5
	B	Wet	72	18	15.19	—	Trace	17	19	72+	33	4.85	25	578-6
	B	Wet	88	24	18.82	—	Trace	37	34	88+	33	4.88	24	578-7
	B	Wet	96	30	21.5	—	Trace	38	46	96+	26	4.21	24	578-8
	B	Wet	96	31	21.9	—	Trace	34	48	96+	35	4.99	26	559-5
	B	Wet	96	45	24.3	—	0.6	31	50	90	26	4.00	26	559-6
	B	Wet	96	22	17.98	—	Trace	25	28	96+	40	5.48	25	577-1
	B	Wet	96	13	13.73	—	Trace	27	26	96+	51	6.57	26	577-2
	B	Wet	96	21	17.64	—	Trace	23	28	96+	40	5.40	26	577-3
	B	Wet	96	14	13.70	—	Trace	26	28	96+	44	5.83	26	577-4
419	B	Wet	96	27	19.97	—	Trace	30	40	96+	40	5.50	26	577-5
428	A	Wet	72	32	20.8	—	Trace	46	52	72+	<8	—	18	525-3
428	A	Wet	72	46	23.6	—	Trace	27	47	63	<8	—	18	525-4

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XXIII. SUMMARY OF O-C-D TEST RESULTS ON O-69-2

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no
Temp, F	Metal set	Air	Time, hr	100 F vis change, %	Neut no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
374	C	Dry	96	12	1 30	None	None	0	---	96+	96+	---	---	430-4
↑	C	Dry	192	19	1 79	None	None	0	---	192+	192+	---	---	437-1
↓	D	Wet	96	11	2 65	None	None	0	---	96+	96+	---	---	431-4
374	D	Wet	192	16	4 07	None	None	1	---	192+	192+	---	192	437-2
392	C	Wet	96	24	5 91	None	None	2	---	93	89	3.40	93	454-2
↓	D	Wet	96	15	3 61	None	None	9	---	96+	96+	---	---	454-1
392	F	Wet	96	18	3 95	None	None	0	---	96+	96+	---	---	439-7
401	A	Wet	96	92	11 22	None	None	2	4	58	54	3.60	56	539-1
↑	A	Wet	96	91	11.12	---	None	3	6	60	54	3.61	57	539-2
	A	Wet	96	86	11.22	---	None	2	4	60	55	3.52	57	539-3
	A	Wet	96	82	10.82	---	None	2	5	62	54	3.62	57	539-4
	A	Wet	96	91	11.41	---	None	2	6	65	54	3.53	57	539-5
	A	Wet	96	98	11.35	---	None	2	5	57	53	3.55	56	539-6
	A	Wet	96	85	10.53	---	None	2	7	53	52	3.70	54	519-7
	A	Wet	96	91	11.22	---	None	1	5	53	52	3.54	55	519-8
	B	Wet	96	102	11 78	---	None	2	5	55	49	3.25	53	562-9
	B	Wet	96	86	11.78	---	None	0	4	59	50	3.42	54	562-10
	B	Wet	96	75	11.35	---	None	0	4	69	65	4.10	64	579-1
	B	Wet	96	68	11.29	---	None	2	5	74	68	4.48	63	579-2
	B	Wet	96	82	11.82	---	None	1	5	66	65	4.19	63	579-3
	B	Wet	96	68	11.18	---	None	0	4	71	67	4.10	66	579-4
	B	Wet	96	74	11.71	---	None	2	6	67	65	4.19	63	579-5
	B	Wet	96	94	11 75	---	None	0	4	58	52	3.46	55	579-6
	B	Dry	96	148	12.03	---	None	---	5	33	25	1.88	34	622-7
	B	Dry	96	155	12.39	---	None	---	6	33	25	1.88	34	622-8
	B	Dry	96	149	11.50	---	None	---	5	33	26	1.95	34	633-1
	B	Dry	96	152	11.69	---	None	---	4	33	26	1.95	34	633-2
	B	Dry	96	152	11.62	---	None	---	5	33	26	1.95	34	633-3
	B	Dry	96	158	12.19	---	None	---	4	33	26	1.95	34	633-4
	B	Dry	96	151	11.41	---	None	---	4	31	26	1.95	34	633-5
	B	Dry	96	146	11.55	---	None	---	4	34	26	1.95	35	633-6
	C	Wet	72	43	9.24	Mg	None	9	---	54	48	2.75	55	455-6
	C	Wet	88	50	10 77	Mg, Cu	None	10	15	60	52	3.17	57	492-4
	C	Dry	72	49	8.97	None	None	0	---	54	52	2.22	60	457-5
	C	Dry	96	118	12 95	Mg	None	0	6	52	50	2.21	57	488-8
	D	Wet	96	70	12.66	Mg	None	8	---	69	65	3 87	66	455-5
	D	Wet	96	59	12 08	Mg	None	1	5	77	74	4.15	72	494-6
	E	Wet	96	69	11 32	Mg, Bz	None	0	5	66	62	3 50	65	497-5
	E	Wet	96	76	11 01	Mg	None	0	4	66	61	3.63	64	497-6
↓	F	Wet	96	104	13 49	Mg	None	0	4	60	52	2.88	59	513-1
401	F	Wet	96	105	13.47	Mg	None	0	5	58	51	2 59	58	513-2

TABLE XXIII. SUMMARY OF O-C-D TEST RESULTS ON O-69-2 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp., °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[3] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	F	Wet	96	105	13.15	Mg	None	3	5	61	52	2.65	59	513-3
	F	Wet	96	120	13.91	Mg	None	0	5	56	51	2.59	57	513-4
	F	Wet	96	114	13.65	Mg	None	0	4	59	51	2.59	58	513-5
	F	Wet	96	141	13.60	Mg	None	0	5	58	51	2.59	57	513-6
	I	Wet	96	94	13.16	Mg, Ag	None	0	4	65	61	3.34	65	532-1
	F	Wet	96	91	12.62	Mg, Ag	None	0	4	66	65	3.38	68	532-2
	F	Wet	76	20	5.61	None	None	1	---	76+	73	4.35	67	447-1
	F	Wet	96	53	11.00	None	None	4	7	82	78	5.08	64	472-5
	F	Wet	96	60	11.41	Mg	None	4	8	75	74	4.78	64	472-6
	F	Wet	96	59	11.39	Mg	None	2	5	77	74	4.65	63	472-7
	F	Wet	96	67	12.87	Mg	None	3	5	71	73	4.37	67	472-8
	F	Wet	96	64	12.16	Mg	None	1	5	75	74	4.50	62	480-6
	F	Wet	96	63	11.89	Mg	None	2	6	75	72	4.44	67	480-7
	F	Wet	96	61	11.67	Mg	None	0	5	79	76	4.38	64	480-8
	F	Wet	96	53	11.17	Mg	None	2	---	79	76	4.70	59	441-2
	F	Dry	96	129	10.20	Mg	None	1	5	32	26	1.85	34	491-8
	F	Dry	96	113	10.13	Mg	None	1	5	31	26	1.70	34	485-5
	G	Wet	88	26	5.84	None	None	3	6	88+	81	4.77	70	493-4
	G	Wet	96	53	10.51	None	None	5	8	81	72	4.46	67	468-5
	I	Wet	16	8	0.94	None	None	0	4	16+	16+	---	---	558-1
	I	Wet	24	9	1.45	None	None	0	4	24+	24+	---	---	558-2
	I	Wet	40	12	2.04	None	None	2	5	40+	40+	---	---	558-3
	I	Wet	48	15	2.36	None	None	0	4	48+	48+	---	---	558-4
	I	Wet	64	17	3.41	None	None	1	6	64+	64	3.41	---	558-5
	I	Wet	72	32	7.39	None	None	2	6	65	64	3.41	67	558-6
	I	Wet	88	69	11.00	Mg	Trace	1	5	60	54	2.74	60	558-7
	I	Wet	96	72	11.95	Mg	Trace	1	6	66	64	2.95	68	558-8
	I	Wet	96	87	12.11	Mg	None	0	4	65	55	2.75	64	537-5
	I	Wet	96	94	12.56	Mg	None	0	4	63	53	2.50	61	537-6
	I	Wet	96	84	11.62	Mg	None	3	6	66	64	3.19	68	556-1
	I	Wet	96	86	11.66	Mg	None	1	5	65	62	3.06	67	556-2
	I	Wet	96	83	11.63	Mg	None	0	4	66	64	3.19	68	556-3
	I	Wet	96	90	11.91	Mg	None	0	4	65	61	3.05	66	556-4
	I	Wet	96	85	11.15	Mg	None	0	4	66	62	3.07	66	556-5
	I	Dry	16	8	1.07	None	None	---	3	16+	16+	---	---	613-1
	I	Dry	24	10	1.39	None	None	---	4	24+	24+	---	---	613-2
	I	Dry	40	12	2.01	None	None	---	4	40+	40+	---	---	613-3
	I	Dry	48	20	4.13	None	None	---	4	46	42	2.02	48	613-4
	I	Dry	64	44	8.70	None	None	---	4	47	42	2.02	50	613-5
	I	Dry	72	64	10.22	None	None	---	5	47	42	2.02	50	613-6
401	I	Dry	72	59	10.08	None	None	0	6	53	48	2.25	56	582-1

TABLE XXIII. SUMMARY OF O-C-D TEST RESULTS ON O-69-2 (Cont'd)

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	Air	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
401	I	Dry	72	60	10.08	None	None	0	6	52	48	2.31	56	582-2
↑	I	Dry	72	66	10.04	Mg	None	--	7	46	44	2.17	50	610-1
↕	I	Dry	72	65	10.47	Mg	None	--	8	45	44	2.17	50	610-2
↕	I	Dry	72	61	9.87	Mg	None	--	6	48	44	2 17	51	610-3
↓	I	Dry	72	62	9.70	None	None	--	5	48	44	2.17	51	610-4
401	I	Dry	72	54	9.80	None	None	--	5	49	44	2.17	49	610-5
410	C	Wet	48	25	6.94	None	None	10	--	45	36	3.05	41	456-1
↑	C	Dry	72	95	11.56	Mg	None	8	--	27	16	1.26	31	438-1
↓	D	Wet	72	89	12.92	Mg	None	9	--	37	26	2.75	34	438-2
	F	Wet	27	12	3.90	None	None	0	--	27+	24	3.00	--	443-5
410	F	Wet	72	76	11.08	Mg	None	2	--	34	27	2.88	32	440-7

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XXIV. SUMMARY OF THERMAL STABILITY TEST RESULTS ON O-67-7

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	N_2	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
473	I	Wet	48(b)	-7	0.75	Mg	Trace	—	4	41	48+	—	—	651-1
↑	I	Wet	48(b)	11	0.77	Mg	Trace	—	4	42	48+	—	—	651-2
↑	I	Dry	64(b)	26	0.44	Mg	Trace	—	4	45	64+	—	—	645-1
473	I	Dry	64(b)	7	0.39	Mg	Trace	—	4	64	64+	—	—	645-2
482	B	Wet	96	-10	10.08	—	None	—	4	96+	96+	—	39	649-1
↑	B	Wet	96	-9	10.19	—	None	—	4	96+	96+	—	38	649-2
↑	B	Dry	96	-12	7.46	—	None	—	4	96+	96+	—	42	612-1
↑	B	Dry	96	-11	7.64	—	None	—	4	96+	96+	—	42	612-2
↑	I	Wet	40(b)	11	0.70	Mg	Trace	—	8	26	40+	—	—	649-3
↑	I	Wet	40(b)	11	0 62	Mg	Trace	—	6	40	40+	—	—	649-4
↓	I	Dry	48(b)	102	0.64	Mg	Trace	—	6	27	48+	—	—	612-3
482	I	Dry	48(b)	109	0.65	Mg	Trace	—	7	27	48+	—	—	612-4
491	B	Wet	96	-12	13.95	—	None	—	3	96+	<16	—	26	647-3
↑	B	Wet	96	-12	13.84	—	None	—	4	96+	<16	—	26	647-4
↑	B	Dry	96	-13	10.97	—	None	—	6	96+	<16	—	27	604-1
↑	B	Dry	96	-14	10.44	—	None	—	8	96+	<16	—	28	604-2
↑	I	Wet	24(b)	-4	0.82	Mg	Trace	—	4	18	24+	—	—	647-1
↑	I	Wet	24(b)	-10	0.82	Mg	Trace	—	5	20	24+	—	—	647-2
↑	I	Dry	48(b)	287	0.35	Mg	Trace	—	7	19	48+	—	—	604-3
↓	I	Dry	48(b)	341	0.37	Mg	Trace	—	9	20	48+	—	—	604-4
↓	J	Wet	96	-17	7.52	M-50, Fe, Bz	None	—	14	96+	96+	—	31	670-1
491	J	Wet	96	-16	8.97	M-50, Fe, Bz	None	—	14	96+	96+	—	31	670-2
518	B	Dry	96	-9	22.1	—	0.2	70	72	96+	<8	—	<8	586-8

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.
(b) Test terminated prematurely due to violent refluxing and associated sample temperature drop.

TABLE XXV. SUMMARY OF THERMAL STABILITY TEST RESULTS ON O-67-9

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	N_2	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
491	I	Wet	96	0	2.76	Mg, Fe	Trace	—	4	96+	96+	--	—	648-1
491	I	Wet	96	1	2.71	Mg, Fe	Trace	—	4	96+	96+	—	—	648-2
509	B	Wet	96	2	5.62	—	None	—	5	96+	96+	—	48	652-1
↑	B	Wet	96	1	5.65	—	None	—	5	96+	96+	—	54	652-2
↕	I	Wet	96	14	4.56	Mg, M-50, Fe	Trace	—	5	92	96+	—	81	652-3
↓	I	Wet	96	14	4.13	Mg, Fe	Trace	—	5	91	96+	—	89	652-4
	I	Dry	96	8	2.71	Mg, M-50, Fe	None	—	8	93	96+	—	—	636-1
509	I	Dry	96	8	2.78	Mg, M-50, Fe	None	—	6	93	96+	—	—	636-2
527	B	Wet	96	10	9.65	—	None	—	8	96+	72	7.80	21	653-1
↑	B	Wet	96	11	9.88	—	None	—	9	96+	67	7.35	21	653-2
	B	Dry	96	4	6.33	—	None	—	5	96+	96+	—	38	619-1
	B	Dry	96	4	6.57	—	None	—	5	96+	96+	—	38	619-2
↕	I	Wet	96	54	8.06	Mg, M-50, Fe	Trace	—	11	51	69	4.91	44	653-3
	I	Wet	96	46	6.62	Mg, M-50, Fe	Trace	—	10	52	71	4.64	50	653-4
↓	I	Dry	96	73	4.43	Mg, M-50, Fe	5.6	—	19	57	96+	—	62	619-3
527	I	Dry	96	72	5.53	Mg, M-50, Fe	4.4	—	20	57	96+	—	62	619-4
536	B	Dry	96	9	9.54	—	None	—	10	96+	<16	—	23	589-1
↑	B	Dry	96	9	9.70	—	None	—	14	96+	<16	—	23	589-2
↓	I	Dry	96	60	3.31	Mg, M-50, Fe	1	—	18	44	96+	—	57	627-1
536	I	Dry	96	82	6.10	Mg, M-50, Fe	2	—	21	44	96+	—	68	627-2
545	I	Dry	96	89	7.79	Mg, M-50, Fe	2	—	22	35	51	4.68	44	630-1
545	I	Dry	96	74	6.06	Mg, M-50, Fe	3	—	16	36	68	5.15	44	630-2
554	B	Dry	96	39	13.10	—	None	—	15	96+	<8	—	9	592-1
554	B	Dry	96	38	12.19	—	None	—	16	96+	<8	—	9	592-2

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign

TABLE XXVI. SUMMARY OF THERMAL STABILITY TEST RESULTS ON O-67-20

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	N_2	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
491	I	Wet	96	2	0.21	Mg	None	--	5	96+	96+	--	--	648-3
491	I	Wet	96	2	0.26	Mg	None	--	5	96+	96+	--	--	648-4
518	I	Dry	96	2	0.26	--	None	--	14	96+	96+	--	--	586-4
536	B	Dry	96	3	0.44	--	None	--	24	96+	96+	--	--	589-3
536	B	Dry	96	4	0.47	--	None	--	31	96+	96+	--	--	589-4
554	B	Dry	96	4	0.59	--	None	--	25	96+	96+	--	--	592-4
572	B	Dry	96	4	0.75	--	None	--	27	96+	96+	--	--	594-1
572	B	Dry	96	4	0.79	--	None	--	26	96+	96+	--	--	594-2
581	I	Dry	96	6	2.00	Mg, M-50, Fe	Trace	--	16	96+	96+	--	--	644-1
581	I	Dry	96	6	1.60	Mg, M-50, Fe	Trace	--	10	96+	96+	--	--	644-2
590	B	Wet	96	7	2.38	--	Trace	--	18	96+	96+	--	--	657-1
↑	B	Wet	96	6	2.49	--	Trace	--	23	96+	96+	--	--	657-2
	B	Dry	96	6	0.19	--	None	--	13	96+	96+	--	--	596-1
	B	Dry	96	6	0.14	--	None	--	10	96+	96+	--	--	596-2
	I	Wet	96	11	4.77	Mg, M-50, Fe	0.2	--	30	96+	96+	--	71	657-3
	I	Wet	96	9	3.96	Mg, M-50, Fe	0.4	--	29	96+	96+	--	--	657-4
↓	I	Dry	96	6	1.62	Mg, M-50, Fe	1	--	36	96+	57	2.14	68	596-3
590	I	Dry	96	6	5.70	Mg, M-50, Fe	Trace	--	18	96+	71	2.43	82	596-4
608	B	Wet	96	8	2.62	--	Trace	--	36	96+	96+	--	--	658-1
↑	B	Wet	96	8	2.50	--	Trace	--	34	96+	96+	--	--	658-2
	B	Dry	96	9	0.70	--	None	--	20	96+	96+	--	--	600-1
	B	Dry	96	8	0.72	--	None	--	14	96+	96+	--	--	600-2
	I	Wet	96	10	5.17	Mg, M-50, Fe, Bz	Trace	--	18	96+	<16	--	21	658-3
	I	Wet	96	9	4.23	Mg, M-50, Fe, Bz	Trace	--	20	96+	<16	--	22	658-4
↓	I	Dry	96	14	3.70	Mg, M-50, Fe	Trace	--	30	96+	30	2.22	39	600-3
608	I	Dry	96	19	2.10	Mg, M-50, Fe	2	--	33	96+	32	2.21	41	600-4
644	B	Wet	96	19	2.18	--	Trace	--	49	96+	96+	--	--	666-1
↑	B	Wet	96	18	1.84	--	Trace	--	59	96+	96+	--	--	666-2
	B	Dry	96	25	0.70	--	Trace	--	46	96+	96+	--	--	607-1
644	B	Dry	96	22	0.86	--	Trace	--	48	96+	96+	--	--	607-2

(a) Defined as a weight change of ±0.20 mg/cm² or more. A weight increase is indicated by a "+" sign.

TABLE XXVII. SUMMARY OF THERMAL STABILITY TEST RESULTS ON O-68-17

Test conditions				End of test results						100°F vis BP, hr	Neutralization number data			Test no.
Temp, °F	Metal set	N_2	Time, hr	100°F vis change, %	Neut. no., mg KOH/g	Metal[a] attack	Sludge, vol %	Deposit rating			BP, hr	Neut. no. at BP, mg KOH/g	Test time to 4 mg KOH/g, hr	
								Revised	Light meter					
473	I	Wet	48(b)	11	0.86	Mg	Trace	--	4	48+	48+	--	--	651-3
↑	I	Wet	48(b)	12	0.81	Mg	Trace	--	5	48+	48+	--	--	651-4
↓	I	Dry	72(b)	20	0.63	Mg	Trace	--	4	66	72+	--	--	645-3
473	I	Dry	72(b)	4	0.67	Mg	Trace	--	4	72+	72+	--	--	645-4
482	I	Wet	40(b)	13	0.63	Mg	Trace	--	4	40+	40+	--	--	649-5
482	I	Wet	40(b)	12	0.64	Mg	Trace	--	4	40+	40+	--	--	649-6
491	B	Wet	96	4	13.05	--	None	--	4	96+	63	7.87	24	647-5
↑	B	Wet	96	4	12.72	--	None	--	5	96+	64	7.79	25	647-6
	B	Dry	96	3	7.17	--	None	--	10	96+	96+	--	50	639-3
	B	Dry	96	2	7.06	--	None	--	10	96+	96+	--	52	639-4
	I	Wet	24(b)	-11	0.86	Mg	0.4	--	5	24+	24+	--	--	648-5
	I	Wet	24(b)	-11	0.72	Mg	0.2	--	7	24+	24+	--	--	648-6
↓	I	Dry	48(b)	185	0.71	Mg	Trace	--	3	26	48+	--	--	639-1
491	I	Dry	48(b)	52	0.71	Mg	Trace	--	4	33	48+	--	--	639-2
509	B	Wet	96	8	18.78	--	None	--	6	96+	<16	--	<16	660-1
↑	B	Wet	96	8	18.23	--	None	--	7	96+	<16	--	<16	660-2
	B	Dry	96	6	11.69	--	None	--	7	96+	<16	--	20	636-3
	B	Dry	96	6	11.78	--	None	--	7	96+	<16	--	20	636-4
	I	Wet	20(b)	1	0.78	Mg	Trace	--	5	<16	20+	--	--	660-3
	I	Wet	20(b)	5	0.77	Mg	Trace	--	5	<16	20+	--	--	660-4
	I	Dry	16(b)	-3	0.66	Mg	Trace	--	4	16+	16+	--	--	636-5
↓	I	Dry	16(b)	0.1	0.77	Mg	Trace	--	5	16+	16+	--	--	636-6
	J	Wet	96	8	18.99	Fe	Trace	--	5	96+	<16	--	<16	660-5
509	J	Wet	96	10	21.1	Fe	Trace	--	6	96+	<16	--	<16	660-6
518	B	Wet	96	13	26.3	--	Trace	--	8	96+	<16	--	<16	662-1
↓	B	Wet	96	11	23.7	--	Trace	--	8	96+	<16	--	<16	662-2
518	B	Dry	96	10	16.45	--	None	--	11	96+	<8	--	10	586-6

(a) Defined as a weight change of ±0.20 mg/cm^2 or more. A weight increase is indicated by a "+" sign.
(b) Test terminated prematurely due to violent refluxing and associated sample temperature drop.

LIST OF REFERENCES

1. Cuellar, J.P., and Baber, B.B., "Evaluation Study of the Oxidation-Corrosion Characteristics of Aircraft Turbine Engine Lubricants," *AFAPL Technical Report 70-10,* Vol. I, May 1970.

2. Cuellar, J.P., and Baber, B.B., "Evaluation Study of the Oxidation-Corrosion-Deposition Characteristics of Aircraft Turbine Engine Lubricants," *AFAPL Technical Report 70-59,* Vol. I, October 1970.

3. Baber, B.B., Cuellar, J.P., Ku, P.M., et al., "Development of Lubricant Screening Tests and Evaluation of Lubricants for Gas Turbine Engines for Commercial Supersonic Transport," *ASD Technical Documentary Report 63-264,* Part I, March 1963.

4. Brownlee, K.A., **Industrial Experimentation,** Chemical Publishing Co., Inc., New York, N. Y., 1952.

5. Baber, B.B., Cuellar, J.P., and Montalvo, D.A., "Deposition and Degradation Characteristics of Aircraft Turbine Engine Lubricants," *AFAPL Technical Report 70-8,* Vol. I, June 1970.